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The fate and effects of a spill of six to eight million gallons of waste crankcase oil rerefined sludge into the Schuylkill River, Pa., in June of 1972 have been studied. The spilled oil contained high concentrations of heavy metals and aliphatic and aromatic hydrocarbons. The spill occurred during a flood, and riverbank trees were coated with oil. Levels of lead were higher in downstream trees; however, no direct permanent effects were noted. Levels of heavy metals in river waters remained below those set by the U.S. Public Health Service for drinking water supplies; however, higher concentrations of lead and zinc were observed downstream. Levels of lead in sediments were higher downstream. Concentrations of petroleum hydrocarbons in sediments were higher at downstream stations. Concentrations of lead in downstream benthic macrofauna were higher.

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ENVIRONMENTAL EFFECTS OF SCHUYLKILL OIL SPILL II (June 1972)

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER PROGRAM OPERATIONS

WASHINGTON, D.C. 20460

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SPRINGFIELD, VA. 22161

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ENVIRONMENTAL EFFECTS OF SCHUYLKILL OIL SPILL II

June 1972

By
Division of Oil and Special Materials Control
Office of Water Program Operations
U.S. Environmental Protection Agency
Washington, D.C. 20460

December 1975

Under Contract
68-01-0781

FOREWORD

Since 1971, the Environmental Protection Agency has supported a program for studying the effects of oil pollution under special contractual arrangements providing for a multi-disciplinary, fast response, field survey team. This study was activated under such an agreement to investigate the impact of a spill of six to eight million gallons of sludge from ruptured dikes at a waste crankcase oil re-refinery plant in the aftermath of Hurricane Agnes. The main section of this report is devoted to detailed chemical and biological data on the distribution and occurrence of hydrocarbon residues and heavy metals in the aquatic environment. In the section entitled recommendations, the report suggests use of cleanup techniques that are least damaging to vegetation, and what corrective measures can be taken to prevent erosion.

Results from this and similar studies are intended to provide a better understanding of the multiple pathways oil can follow when discharged into the aquatic ecosystem. Furthermore, such investigations will assist in the formulation of regulations, policies and procedures that are most effective in the removal of oil from water.

This report is intended for use by government, industry, and other interested parties. I want to express my sincere thanks and appreciation for all who participated in the successful completion of this project.

H. D. Van Cleave
Chief, Spill Prevention & Control Branch
Oil & Special Materials Control Division
Office of Water Program Operations
Washington, D. C. 20460

NOTICE

This report has been reviewed by the Oil and Special Materials Control Division, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

The fate and effects of a spill of six to eight million gallons of waste crankcase oil rerefined sludge into the Schuylkill River, Pa., in June of 1972 have been studied. The spilled oil contained high concentrations of heavy metals and aliphatic and aromatic hydrocarbons. The spill occurred during a flood, and riverbank trees were coated with oil. Levels of lead were higher in downstream trees; however, no direct permanent effects were noted. Levels of heavy metals in river waters remained below those set by the U. S. Public Health Service for drinking water supplies; however, higher concentrations of lead and zinc were observed downstream.

Levels of lead in sediments were higher downstream. Concentrations of petroleum hydrocarbons in sediments were higher at downstream stations. Concentrations of lead in downstream benthic macrofauna were higher. Immediately downstream from the spill, there was evidence of environmental degradation not observed upstream or further downstream.

Recommendations for handling of similar spills have been formulated.

TABLE OF CONTENTS

Page

SUMMARY 1

CONCLUSIONS 4

RECOMMENDATIONS 5

INTRODUCTION 6

MATERIALS AND METHODS 12

1. Description of Sampling Stations 12
2. Analyses of Vegetation 15
3. Physical and Chemical Analyses of River Water 15
4. Heavy Metals Analyses 15
5. Petroleum Hydrocarbon Analyses 18
6. Biological Analyses of River Biota 24
7. Observations of Shore Cleanup Impact and Effectiveness 27

RESULTS AND DISCUSSION 28

1. Properties of Spilled Crankcase Oil Waste 28
2. Effects of the Oil Spill on Vegetation 28
3. Physical and Chemical Parameters of Schuylkill River Water 41
4. Concentrations of Metals in Schuylkill River Water 42
5. Heavy Metals in Sediments 42
6. Petroleum Hydrocarbons in Schuylkill River Sediments 46
7. Heavy Metals in Benthic Macrofauna and Fishes 46
8. Petroleum Hydrocarbons in Fishes 48
9. Other Effects of the Oil Spill on River Biota 94
10. Cleanup Impact and Effectiveness 101

ACKNOWLEDGEMENTS 106

REFERENCES 107

TABLE OF CONTENTS
(Continued)

Page

GLOSSARY 110

APPENDICES 111

LIST OF FIGURES

FIGURE NUMBER	TITLE	PAGE
1	Map of Schuylkill River Area	8
2	Monocacy Sampling Stations	9
3	Douglassville Sampling Stations	10
4	Parker Ford Sampling Stations	11
5	Extensively Oiled Riverbank Vegetation	31
6	Oil-Coated Riverbank Vegetation Along the Banks of the Schuylkill River in July, 1972	32
7	Oil-Coated Ornamental Evergreens 10 Days After the Oil Spill	34
8	Oiled Evergreens 1 Year After the Oil Spill	35
9	Cross-Section of Oiled Oak Bark Magnified 613X	37
10	Concentrations of Lead in Schuylkill River Water from 3 July to 4 August 1972	43
11	Concentrations of Lead, Zinc, Cadmium, Copper, and Mercury in Schuylkill River Sediments Collected in November, 1972	44
12	Relative Concentrations of Petroleum Hydrocarbons in Schuylkill River Sediments Collected in November, 1972	47
13	Infrared Spectrum of Cyclohexane Fraction from Spilled Crankcase Oil Waste (SCOW) Collected in July, 1972	56
14	Infrared Spectrum of Cyclohexane Fraction from Downstream White Suckers Collected in July, 1973	56
15	Infrared Spectrum of Cyclohexane Fraction from Upstream White Suckers Collected in July, 1973.	58
16	Infrared Spectrum of Cyclohexane Fraction from Downstream Brown Bullheads Collected in July, 1973	58

LIST OF FIGURES
(Continued)

FIGURE NUMBER	TITLE	PAGE
17	Infrared Spectrum of Benzene and Benzene/ Ether Fraction from Downstream White Suckers Collected in July, 1973	59
18	Infrared Spectrum of Benzene and Benzene/ Ether Fraction from Upstream White Suckers Collected in July, 1973	59
19	Infrared Spectrum of Benzene and Benzene/ Ether Fraction from Downstream Brown Bullheads Collected in July, 1973	60
20	Infrared Spectrum of Benzene and Benzene/ Ether Fraction from Downstream Crappies Collected in July, 1973	60
21	Infrared Spectrum of Benzene Fraction from Spilled Oil Collected in July, 1972	61
22	Infrared Spectrum of Benzene/Ether Fraction from Spilled Oil Collected in July, 1972	61
23	Infrared Spectrum of Benzene Fraction from Rerun of Column Chromatogram of Spilled Oil Collected in July, 1972	62
24	Chromatogram of Cyclohexane Fraction from Spilled Oil Collected in July, 1972	64
25	Chromatogram of Benzene Fraction from Spilled Oil Twice Collected in July, 1972	65
26	Chromatogram of Cyclohexane Fraction from Upstream White Suckers Collected in July, 1973	66
27	Chromatogram of Cyclohexane Fraction from Downstream White Suckers Collected in July, 1973	67
28	Chromatogram of Cyclohexane Fraction from Downstream Brown Bullheads Collected in July, 1973	68
29	Chromatogram of Cyclohexane Fraction from Downstream Crappies Collected in July, 1973	69

LIST OF FIGURES
(Continued)

FIGURE NUMBER	TITLE	PAGE
30	Chromatogram of Benzene Fraction from Upstream White Suckers Collected in July, 1973	71
31	Chromatogram of Benzene Fraction from Downstream White Suckers Collected in July, 1973	72
32	Chromatogram of Benzene Fraction from Downstream Brown Bullheads Collected in July, 1973	73
33	Chromatogram of Benzene Fraction from Downstream Crappies Collected in July, 1973	74
34	Standard Polycyclic Aromatic Hydrocarbons	75
35	Chromatogram of Polycyclic Aromatic Hydrocarbons each 0.116 mg/ml in Benzene	77
36	Chromatogram of Benzene Fraction from Upstream White Suckers Doped with Benzo (a) Pyrene	78
37	Chromatogram of Benzene Fraction from Upstream White Suckers Doped with 1, 2 - Benzanthracene	79
38	Chromatogram of Benzene Fraction from Upstream White Suckers Doped with Chrysene	80
39	Chromatogram of Benzene Fraction from Upstream White Suckers Doped with Flouranthene	81
40	Chromatogram of Benzene Fraction from Upstream White Suckers Doped with Pyrene	82
41	Chromatogram of Benzene Fraction from Upstream White Suckers Doped with Pehenanthrene	83
42	Chromatogram of Benzene Fraction from Column Chromatogram of Harrison Lake National Fish Hatchery Channel Catfish without TPM Internal Standard and with 5 ppm added Hydrocarbon	88

LIST OF FIGURES
(Continued)

FIGURE NUMBER	TITLE	PAGE
43	Chromatogram of Standard Polycyclic Aromatic Hydrocarbons with Triphrnylmethane (TPM) Internal Standard	89
44	Chromatogram of Benzene Fraction from Column Chromatogram of Harrison Lake National Fish Hatchery Channel Catfish with TPM Internal Standard and Zero ppm Added Hydrocarbon	90
45	Chromatogram of Benzene Fraction from Column Chromatogram of Harrison Lake National Fish Hatchery Channel Catfish with TPM Internal Standard and 2 ppm Added Hydrocarbon	91
46	Chromatogram of Benzene Fraction from Column Chromatogram of Harrison Lake National Fish Hatchery Channel Catfish with TPM Internal Standard and 5 ppm Added Hydrocarbon	92
47	Chromatogram of Benzene Fraction from Column Chromatogram of Harrison Lake National Fish Hatchery Channel Catfish with TPM Internal Standard and 10 ppm Added Hydrocarbon	93
48	Chlorophyll a Pheopigments of Schuylkill River Water During July, 1972	96
49	Ranges of Abundance of Three Dominant Zooplankton Taxons Collected on 28 July and 29 November 1972 in the Schuylkill River	98
50	Ranges of Abundance of Two Dominant Macrofaunal Taxons Collected on 29 November 1972 and 28 July 1973 in the Schuylkill River	99
51	Daily Oxygen Metabolism of Schuylkill River Biota on 30 July 1972 at Monocacy Bridge	102
52	Daily Oxygen Metabolism of Schuylkill River Biota on 30 July 1972 at Parker Ford Bridge	103

LIST OF TABLES

TABLE NUMBER	TITLE	PAGE
1	Location and Characteristics of Schuylkill River Sediment Sampling Sites	14
2	Constituents of Spilled Crankcase Oil Waste Collected Near Douglassville Bridge in July, 1972	29
3	Heavy Metal Concentrations in Waste Crankcase Oil Samples Collected and Analyzed in 1971 by the U. S. Environmental Protection Agency	30
4	Heavy Metal Concentrations in Tree Leaves Collected from Monocacy Farm in May, 1973	38
5	Heavy Metal Concentrations in Tree Leaves Collected Near the Douglassville Bridge in May, 1973	39
6	Heavy Metal Concentrations in Tree Leaves Collected Near the Pottstown Bridge (Route 100) in May, 1973	40
7	Comparison of Metals in Schuylkill River and Potomac River Sediments	45
8	Levels of Aliphatic and Aromatic Hydrocarbons in Schuylkill River Fish Collected July, 1973	84

LIST OF APPENDICES

APPENDIX NUMBER PAGE

I DATA FROM ANALYSES OF RIVER WATER

1. 24 Hour Temperature and Dissolved Oxygen July, 1972 112

2. Biochemical Oxygen Demand, Chemical Oxygen Demand, and M.O. Alkalinity of Schuylkill River Water Above and Below Spill Site in July, 1972 114

3. Hydrogen-ion Concentration in Schuylkill River Water 12 July - 5 August 1972 116

II DATA FROM HEAVY METALS ANALYSES OF RIVER WATER AND SEDIMENTS

1. Concentrations of Lead, Zinc, Cadmium, and Copper in Schuylkill River Water 3 July - 4 August 1972 119

2. Concentrations of Lead, Zinc, Cadmium, and Copper in Schuylkill River Bottom Samples Collected in July, 1972 127

III DATA FROM HYDROCARBON ANALYSES OF SEDIMENTS

1. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Control Station M 131

2. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station D-1 132

3. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station D-2 133

APPENDIX NUMBER PAGE

III (cont.)

4. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station D-3 135

5. Chromatogram of Oil in Sediment Subsample Collected in November, 1972, at Station D-3 136

6. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station D-4 137

7. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station D-5 138

8. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station P-1 139

9. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station P-2 140

10. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station P-3 141

11. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station P-4 142

12. Chromatogram of Oil in Sediment Composite Collected in November, 1972, at Station P-5 143

IV DATA FROM HEAVY METALS ANALYSES OF RIVER BIOTA

1. Concentrations of Lead, Zinc, Cadmium, and Copper in Benthic Macrofauna Collected in July, 1973 145

2. Concentrations of Lead, Zinc, Cadmium, Copper, and Mercury in White Suckers Collected in November, 1972; January and July, 1973 146

3. Concentrations of Lead, Zinc, Cadmium, Copper, and Mercury in Brown Bullheads Collected in November, 1972; January and July, 1973 147

APPENDIX NUMBER | | PAGE

IV (cont.)

4. Concentrations of Lead, Zinc, Cadmium, Copper, and Mercury in Crappies Collected in November, 1972; January and July, 1973 148

5. Concentrations of Lead, Zinc, Cadmium, Copper, and Mercury in Bluegills Collected in November, 1972, and January, 1973 149

6. Concentrations of Lead, Zinc, Cadmium, and Copper in Schuylkill River Fishes Collected 19 and 22 July 1972 150

7. Concentrations of Lead, Zinc, Cadmium, and Mercury in Schuylkill River Fishes Collected 23 and 29 July 1972 151

V HYDROCARBON IN FISHES

1. Extraction Data 153

2. Saponification Data 154

3. Column Chromatographic Data 155

4. Extraction and Saponification Results from Harrison Lake National Fish Hatchery Fish 159

5. Column Chromatographic Data Harrison Lake National Fish Hatchery Fish 160

6. Peak Area and Weight Correlations of Polycyclic Aromatic Hydrocarbons Compared to Triphenylmethane Internal Standard 161

7. Percent Recovery of Polycyclic Aromatic Hydrocarbons from Harrison Lake National Fish Hatchery Fish (2 ppm added Hydrocarbon) 162

APPENDIX NUMBER		PAGE
V (cont.)	8. Percent Recovery of Polycyclic Aromatic Hydrocarbons from Harrison Lake National Fish Hatchery Fish (5 ppm added Hydrocarbon)	163
	9. Percent Recovery of Polycyclic Aromatic Hydrocarbons from Harrison Lake National Fish Hatchery Fish (10 ppm added Hydrocarbon)	164
VI	DATA FROM BIOLOGICAL ANALYSES	
	1. Chlorophyll a Content of Schuylkill River Water Above and Below the Oil Spill Site in July, 1972	166
	2. Zooplankton Abundance in Schuylkill River Water Above and Below the Oil Spill Site in July, November, and December, 1972, and July, 1973	168
	3. Benthic Macrofauna Abundance in Schuylkill River Sediments in November, 1972, and July, 1973	174
	4. Counts of Bacteria in Schuylkill River Sediments (Organisms/g of Sediment) Above and Below Oil Spill in July, 1972	184
	5. Stomach Contents of Fishes Collected from the Schuylkill River in Winter, 1972, and Summer, 1973	185

SUMMARY

Six million gallons of rerefined waste crankcase oil sludge spilled into the Schuylkill River near Douglassville, Pennsylvania, in June of 1972. This report summarizes a study of both the immediate and the long-term effects of the spill.

The spilled oil coated and caused extensive temporary damage to vegetation along approximately 17 miles of riverbank. Most trees and herbaceous species lost their leaves, thus the aesthetic value of the riverbanks was impaired during the summer of 1972. Some oil-coated branches were killed. Some dead branches have been invaded by wood-rotting fungi that may in time damage the trees.

The spilled oil did not cause direct permanent damage to deciduous species along the riverbank; however, many ornamental evergreens have been seriously damaged and have lost their aesthetic value.

Leaves on trees in the heavily affected downstream areas had significantly higher lead levels than leaves from trees in the area immediately upstream from the spill site in the summer of 1973. However, lead levels were not higher than levels in urban trees reported in the literature.

Concentrations of the heavy metals, lead, zinc, cadmium, and copper in Schuylkill River water downstream from the spill site in July, 1972, were below permissible levels for drinking water supplies set by the U. S. Public Health Service.

Lead and zinc levels in the Schuylkill River water were higher in the downstream areas than at the immediately upstream site during early July, 1972. In mid-late July, 1972, concentrations of lead and zinc had generally decreased to background levels.

Lead levels in Schuylkill River sediments collected during November, 1972, were significantly higher in the downstream areas than immediately upstream.

Petroleum hydrocarbon concentrations in sediments collected in November, 1972, from the downstream areas were significantly higher than in sediments from the upstream station at Monocacy. Comparison of the gas chromatograms of oil in the sediments suggests that

the spill was responsible in part for the high petroleum hydrocarbon concentrations at downstream stations.

Lead concentrations in Diptera larvae and Oligochaete worms collected in July, 1973, were three to seven times higher in the immediately downstream area than in the immediately upstream area.

Heavy metals concentrations in fishes collected from the Schuylkill River in July, 1972; November, 1972; January, 1973; and July, 1973, were similar at both upstream and downstream sample stations.

Aromatic and aliphatic hydrocarbon concentrations were similar in upstream and downstream fish collected in July, 1973, but are markedly higher than concentrations in fish from a pure environment.

Zooplankton samples taken on 16 July 1972 and 14 July 1973 indicated no differences in taxon diversity between upstream and downstream lengths of the river that can be attributed to the oil spill.

Macrofauna samples collected five and thirteen months after the spill (29 November 1972 and 28 July 1973) indicated no differences between upstream and downstream lengths of the river that can be attributed to the oil spill.

Chemical oxygen demand (COD) during July, 1972, was greatest in the length of the river downstream from the spill site between Douglassville Bridge and Spring City Bridge. A substantially greater amount of pheopigment level characterized Parker Ford, downstream from the spill site, on 29 July 1972. Repspiration of the biotic community at Parker Ford was marginally greater on 30 July 1972 than at the immediately upstream site. Bacteria (including hydrocarbon oxidizers) consistently reached peak levels at the Parker Ford Bridge station. Each of the above observations, taken separately, offers only weak evidence of environmental differences among upstream and downstream lengths of the river. Collectively, they present circumstantial evidence that the length of the river between Douglassville Bridge and Spring City Bridge (0.7 - 16.5 miles below the oil spill) was characterized by a degree of environmental degradation not evident immediately upstream or downstream.

Existence of numerous actual and potential sources of pollution in the Douglassville Bridge - Spring City Bridge length of the river preclude positive assignment of the oil spill as the cause of environmental degradation. However, the oil spill could quite plausibly have resulted in both the high COD and pheopigment content that was observed in this length of the river. These conditions, in turn, could be expected to stimulate a buildup of bacterial decomposers which would cause the increased community respiration that was detected by the diurnal oxygen-curve technique.

CONCLUSIONS

The rerefinery sludge temporarily damaged deciduous trees and other vegetation along the riverbanks by causing premature loss of leaves and reduction of aesthetic values during the summer of 1972. Recovery from this contamination by the summer of 1973 was evident. Evergreen trees and ornamental evergreen shrubs were permanently damaged by rerefinery sludge as evidenced by loss of needles from affected branches.

Although flood conditions on the Schuylkill had an overriding influence on many of the aquatic aspects of the study, environmental degradation due to rerefinery sludge and associated heavy metals was obvious as late as thirteen months after the spill.

Heavy metal concentrations in the river remained below those concentrations listed as prohibitory for drinking water by the U. S. Public Health Service.

Techniques used in the removal operation represented the best practice available for the problems encountered. These techniques included:

. Oil deposited on the land areas was physically removed. Care was taken not to bury removed oil where contamination to ground water or livestock might occur.

. Only trees, shrubs, and branches in the most heavily polluted areas were removed in order to leave a root system to prevent bank erosion.

. "Quick-cover", fast growing grass was used to prevent erosion of river banks, following physical removal of oil.

RECOMMENDATIONS

In the event of a spill of similar material near a stream or river:

1. Immediately mobilize quick-response study teams to analyze the impact of the spill.

2. Utilize cleanup techniques that do the least harm to trees and vegetation including:

    A. Remove oil from the ground using hand implements so as not to disturb root systems and cause erosion.

    B. Remove only downed trees and heavily coated brush without unnecessarily disturbing the soil.

INTRODUCTION

On 22 June 1972 floods caused by heavy rains from Hurricane Agnes inundated oil storage lagoons on the banks of the Schuylkill River near Douglassville, Pennsylvania. The lagoons contained residue from several years of operation of a petroleum rerefining plant employing the vacuum distillation process. The plant rerefined waste crankcase oil collected from service stations and garages. A byproduct of the rerefined process was a thick, tarry residue which could not be economically reduced or used. An estimated 6 - 8 million gallons was stored in the lagoons at the time of the flood.

The flooding river swept the oil from the lagoons and carried it downstream. Because the flooded Schuylkill was far beyond its usual boundaries, the oil coated trees, homes, and riverbanks as the water receded. Riverbanks on both sides of the river were coated on the average to a distance of 50 yards inland along 17 miles of the river.

A study of the effects of the spill has been conducted during the year following the spill. The objectives of the study were to:

1. Evaluate the severity and extent of damage to vegetation along the river,

2. Determine the health hazard due to heavy metal contamination of drinking water supplies,

3. Determine the constituents of the oil and its fate and effects in the river, and

4. Evaluate the impact and effectiveness of shore clean-up operations and recommend procedures for handling similar spills.

To accomplish the objectives:

--The properties of the spilled crankcase oil waste were determined.

--the recovery of trees along the banks of the Schuylkill was monitored during the summer of 1972 and during fall bud set and spring 1973 leaf formation. In the spring of 1973, the concentrations of heavy metals in tree leaves downstream from the spill were determined and compared to concentrations in leaves of trees from an upstream station.

--physical and chemical parameters of river water were monitored at upstream and downstream stations. Biochemical oxygen demand, chemical oxygen demand, alkalinity, temperature, dissolved oxygen, and hydrogen-ion concentrations were determined during the summer of 1972.

--concentrations of lead, zinc, cadmium, and copper in the Schuylkill River water were determined on a daily basis from 3 July 1972 until 4 August 1972.

--concentrations of the metals lead, zinc, cadmium, and copper, and of petroleum hydrocarbons were determined in Schuylkill River sediment samples collected in November, 1972.

--concentrations of the heavy metals lead, zinc, cadmium, copper, and mercury were determined in macrofauna collected from the river in winter 1972 and summer 1973.

--levels of polycyclic aromatic and aliphatic hydrocarbons were determined in fishes from the Schuylkill River.

--other possible effects of the spill were monitored. Average levels of total and active chlorophyll a were measured in July, 1972. Zooplankton were collected at stations upstream and downstream from the spill,and major taxon diversity was determined. Benthic macrofauna were sampled upstream and downstream from the spill and ranges of abundance of the dominant macrofaunal taxons determined. The types and abundance of bacteria in Schuylkill River sediments were determined during the summer of 1972. Using diurnal curve techniques, community respiration, including that of the bottom community, was determined during July of 1972.

--clean-up operations were monitored, and recommendations were submitted to the EPA on a day-to-day basis during July, 1972. Recommendations for the handling of similar spills are included in this report.

This report summarizes work conducted under Basic Ordering Agreement 68-01-0701, Delivery Order 1, a study of the immediate effects of the spill and work under Contract 68-01-0781, a follow-up study of the longer-term effects of the oil spill.

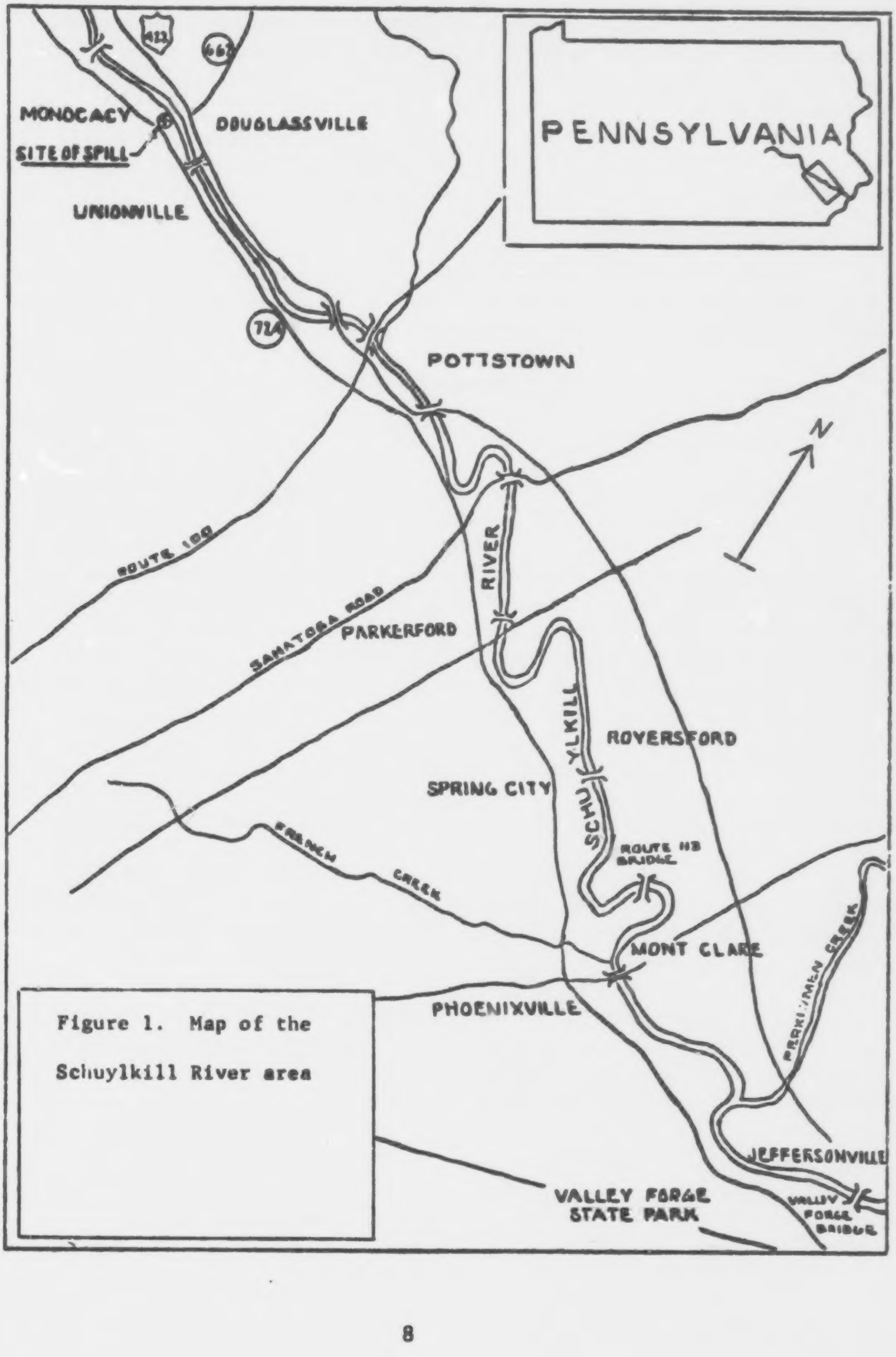
422
662
MONOCACY
DOUGLASSVILLE
SITE OF SPILL
UNIONVILLE
PENNSYLVANIA
724
POTTSTOWN
N
ROUTE 100
RIVER
SANATOGA ROAD
PARKERFORD
SCHUYLKILL
ROYERSFORD
SPRING CITY
ROUTE 113 BRIDGE
FRENCH CREEK
MONT CLARE
PHOENIXVILLE
PERKIOMEN CREEK
JEFFERSONVILLE
VALLEY FORGE STATE PARK
VALLEY FORGE BRIDGE

Figure 1. Map of the Schuylkill River area

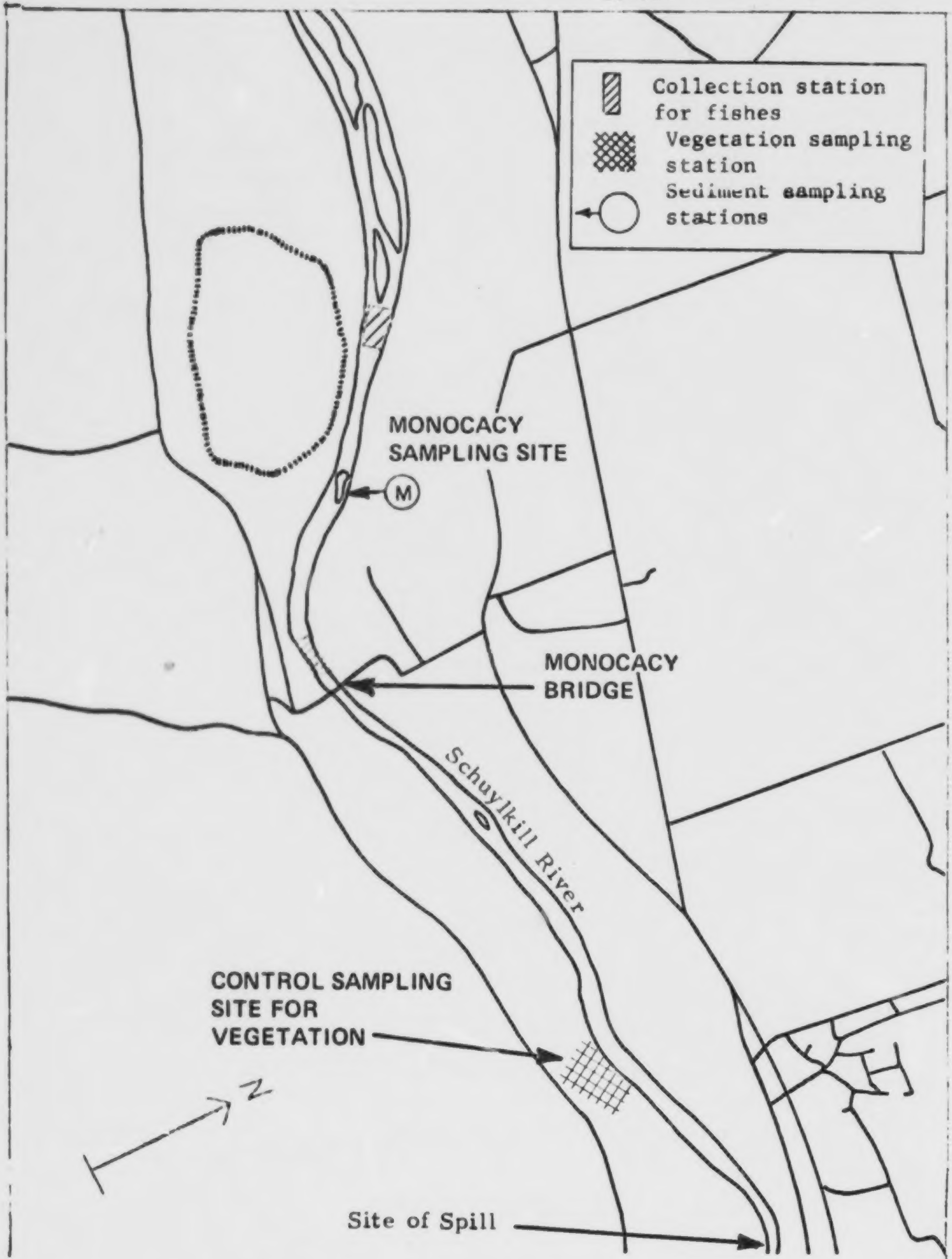
Collection station for fishes
Vegetation sampling station
Sediment sampling stations
MONOCACY SAMPLING SITE
M
MONOCACY BRIDGE
Schuylkill River
CONTROL SAMPLING SITE FOR VEGETATION
N
Site of Spill

FIGURE 2. MONOCACY SAMPLING STATIONS

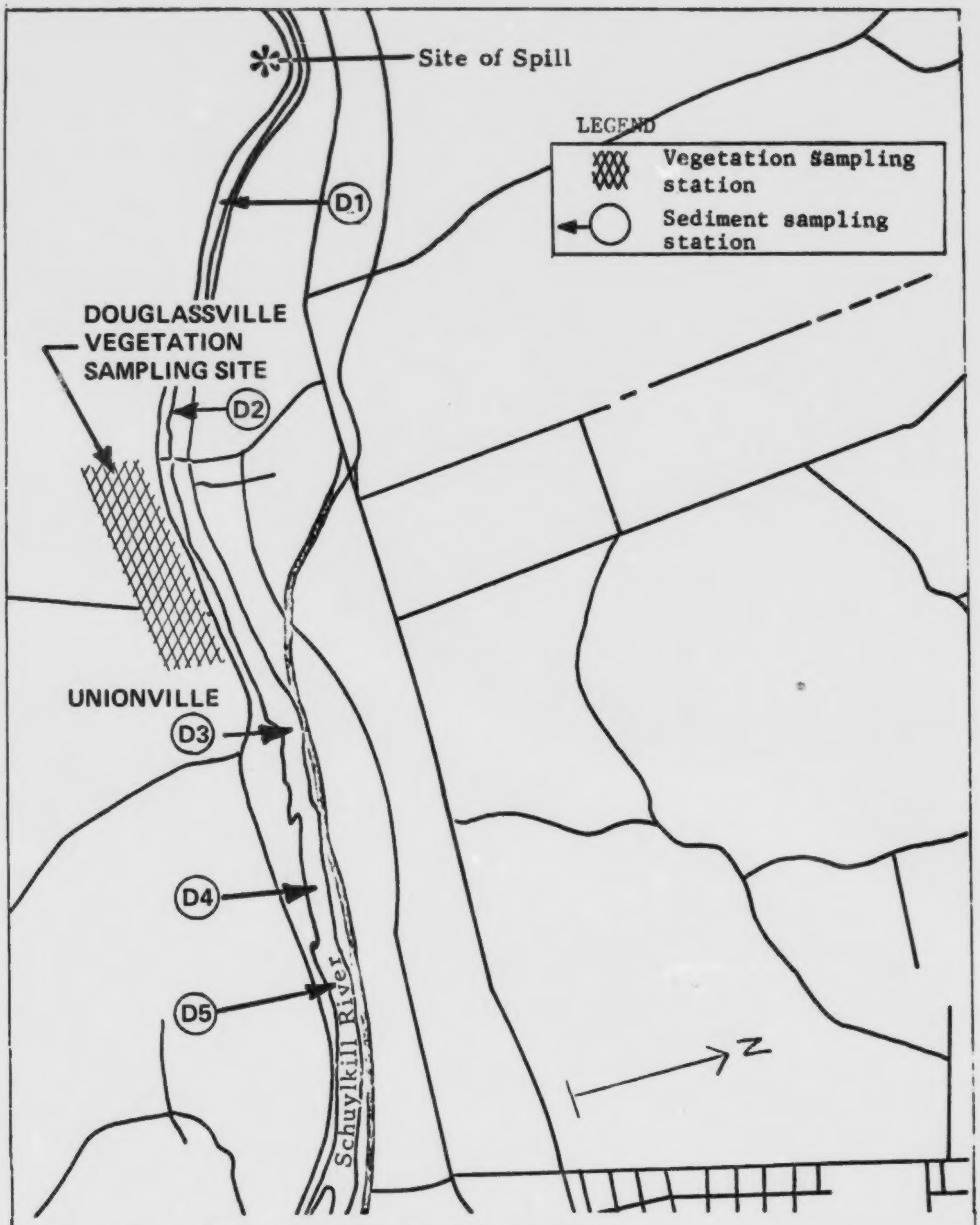
Site of Spill
LEGEND
Vegetation Sampling station
Sediment sampling station
D1
DOUGLASSVILLE VEGETATION SAMPLING SITE
D2
UNIONVILLE
D3
D4
D5
Schuylkill River
N

FIGURE 3. DOUGLASSVILLE SAMPLING STATIONS

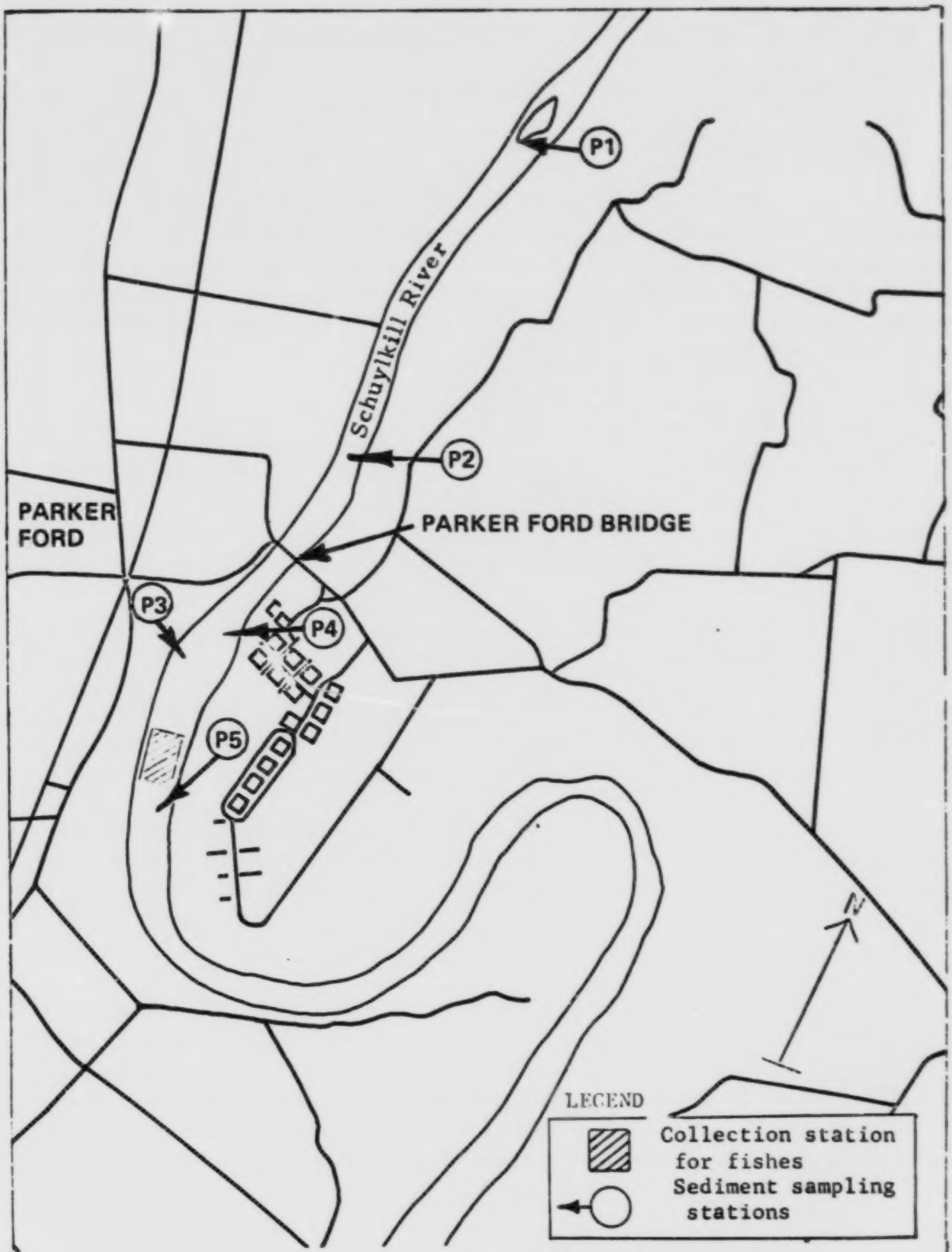
Schuylkill River
P1
P2
P3
P4
P5
PARKER FORD
PARKER FORD BRIDGE
N
LEGEND
▨ Collection station for fishes
Sediment sampling stations

FIGURE 4. PARKER FORD SAMPLING STATIONS

MATERIALS AND METHODS

1. DESCRIPTION OF SAMPLING STATIONS

A. Vegetation

Bark and leaf samples were collected from sampling stations on the banks of the Schuylkill River in heavily oiled areas near Unionville and Pottstown Bridge (Route 100), and from a control station on the southwest bank of the Schuylkill at Monocacy Farm, approximately 1/2 mile upstream from the site of the spill. These stations are shown on Figures 1 through 3.

B. River Water

River water samples for heavy metals and physical and chemical analyses were collected at Monocacy Bridge, Douglassville Bridge, Parker Ford Bridge, Spring City-Royersford Bridge, and Falls Bridge at Philadelphia. These bridge locations are shown on Figure 1.

C. Fishes for Petroleum Hydrocarbon and Heavy Metals Analyses

Fishes were collected at stations in the Monocacy area 1.3 miles upstream from the spill, Figure 2, and from the Parker Ford area, Figure 4, 11 miles below the spill.

For the analysis of fish from a clean environment, channel catfish were taken from Harrison Lake National Fish Hatchery located on Route 5 between Williamsburg and Richmond, Virginia.

D. Sediment

Sediment samples for heavy metals and hydrocarbon analyses were collected in the Monocacy area, 2.1 miles above the oil spill, in the Douglassville area 0.4 and 2.3 miles downstream from the oil spill, and in the Parker Ford area 10.6 to 12.5 miles downstream from the oil spill. Figures 2, 3, and 4 show the locations of these sample stations. The characteristics of each station are shown in Table 1.

E. Benthic Macrofauna

Benthic organisms for biological and heavy metals analyses were collected at the sediment sampling stations discussed above.

F. Zooplankton and Phytoplankton Pigment

Plankton were sampled from Monocacy Bridge and Parker Ford Bridge. Locations of these stations are shown in Figure 1.

TABLE 1 Location and Characteristics of Schuylkill River Sediment Sampling Sites

IDENTIFICATION	DISTANCE FROM SOURCE OF SPILL (Miles)	CHARACTERISTICS
Monocacy		
Monocacy	2.1 above	Downstream edges of small island
Douglassville		
D1	0.4 below	Downstream edge of small island (1-3 ft. deep)
D2	1.0 below	Downstream edge of island (1-3 ft. deep)
D3	1.7 below	Downstream of small islands (1-3 ft. deep)
D4	2.1 below	Behind snag (1-3 ft. deep)
D5	2.3 below	Downstream of small islands (1 ft. deep)
Parker Ford		
P1	10.6 below	Downstream edge of large island (2-4 ft. deep)
P2	11.4 below	Over shoal area (2 ft. deep)
P3	12.0 below	In mouth of creek (6 ft. deep)
P4	12.0 below	Over shoal area (2 ft. deep)
P5	12.5 below	Open river (5-6 ft. deep)

2. ANALYSES OF VEGETATION

Ground and air surveys were made in July, 1972, to determine the extent and severity of damage to trees. Follow-up surveys were conducted in the fall of 1972 and the spring and summer of 1973. Individual specimens of various species were selected within the upstream (Figure 2) and downstream (Figure 3) sampling stations and marked with plastic tape so that their recovery could be monitored during fall bud-set and spring leaf formation. Sections of branches and bark from oil-soaked trees within the sampling stations were removed and placed in vials of fresh Formalin Acetic Acid and Alcohol (FAA) killing and preserving fluid (Sass 1958). Sections were allowed to stand in the killing and preserving fluid for three weeks to become sufficiently rigid. Freehand sectioning was used to obtain thin cross sections that were stained, mounted, and examined to determine the extent and effects of oil penetration.

3. PHYSICAL AND CHEMICAL ANALYSES OF RIVER WATER

Dissolved oxygen was determined in the field using the modified Winkler micromethod with a LaMotte dissolved oxygen kit (Model EDO, Code 7414). Hydrogen-ion concentration (pH) was measured in the field with a LaMotte electrode kit (Model HA , Code 1901).

BOD, COD, and alkalinity were determined per Standard Methods, 13th ed. Samples were collected in polyethylene containers, refrigerated, and delivered to the laboratory within four hours of collection.

4. HEAVY METAL ANALYSES

A. Leaves (Dry Ash Method)

Leaves from the spring 1973 growing season were taken for analysis. They were stored in clean polyethylene bags until analysis. To remove surface contamination, the leaves were washed: they were wet in a 0.1% ivory soap solution, rinsed once in tap water, and then again in distilled water. Ten to fifteen leaves from each species were composited and analyzed for lead, zinc, cadmium, and copper using a dry-ashing technique. The procedure is:

Sass, J. E. 1958. Botanical Microtechnique. Iowa State University Press, Ames, Iowa, 228 p.

(1) Dry leaves for two days at 85 °C.

(2) Grind sample to finely divided particles in a Wiley mill.

(3) Weigh out 1 g of particles into a crucible for dry ashing at 500 °C for one hour in a muffle furnace.

(4) Cool and dissolve ash in 5 ml of 12HCl diluted 19:1.

(5) Take the sample to dryness by evaporating HCl off on hot plate.

(6) Redissolve residue in 4 ml HCl diluted 19:1.

(7) Filter solution through filter paper.

(8) Bring filtrate to 25 Ml in a volumetric flask with distilled water.

(9) Set up standard curves for each element in question, and analyze samples with atomic absorption spectrophotometer (Perkin-Elmer Model 303).

B. River Water

Since the sensitivity of the atomic absorption method is limited by the instrument, organic extractions and concentrations had to be utilized for the metals cadmium and lead.

The procedure used was that of the Environmental Protection Agency as described in: Methods for Chemical Analysis of Water and Wastes (1971).

The values for copper and zinc were obtained by direct aspiration of the water since the permissible levels of these metals for water supplies were above the sensitivity of the instrument.

C. Sediments

Composite samples from ten downstream stations

U. S. Environmental Protection Agency. 1971. Laboratory Branch, Inter-Office Correspondence.

(Figures 3 and 4) and one upstream (control) station (Figure 2) were observed to determine if, and in what quantities, oil had been deposited in the river. Ten to twenty (10-20) subsamples were taken at each site with a .25 ft. Ekman dredge. Attempts were made to sample the upper 2-3 inches of sediment. Samples were stored in clean polyethylene bags.

The non-crystalline forms of lead, zinc, cadmium, copper, and mercury were analyzed using atomic absorption techniques. Since it is likely that the surface area of sediments affects the amount of oil-metals accumulated, each subsample was wet sieved (U. S. standard sieve, No. 230, 63 micron openings) to assure that each composite sample was similar in particle size distribution, thereby allowing a better comparison among locations. The sieved subsamples were than air dried and 1 g portions of each were combined to obtain the composites.

The procedure for extracting lead, zinc, cadmium, and copper is:

(1) Place 1,000 g of samples in an acid-washed Phillips beaker.

(2) Add 5 ml of concentrated HNO_3 (Boxes Ultrex, if possible).

(3) Heat until solution begins to boil, being careful not to lose sample by bumping.

(4) Allow sample to cool. Repeat Steps 2 and 3.

(5) After cooling, add 10 ml of distilled water.

(6) Centrifuge and save supernatent liquid.

(7) Set up standard curves for each element in question and analyze with Varian AA-5 atomic absorption spectrophotometer.

Analyses of replicate samples extracted by this method showed a precision of ± 8% for lead, ± 5% for zinc, ± 3% for cadmium, ± 7% for copper and ±10% for mercury.

The method for mercury consisted of sulfuric acid-potassium permangenate oxidation and a reduction step with hydrooxylamine sulfate--stannous sulfate. The analyses were performed on a Coleman mercury analyzer which had been modified with a quartz flow cell and recorder attachment. This method has been utilized successfully on sediments elsewhere (Huggett, et al; 1971).

D. Biota

Benthic organisms and fishes were analyzed for lead, zinc, cadmium, copper, and mercury after digestion in concentrated nitric acid, as performed by Huggett, et al; (1973).

Replicate analyses of all biota were performed by atomic absorption spectrophotometry using a Varian AA-5 instrument.

5. PETROLEUM HYDROCARBON ANALYSES

A. Sediment

The composite samples, each composed of ten to twenty subsamples, from the ten downstream (Figures 3 and 4) and one upstream (Figure 2) sample sites were extracted and analyzed by flame ionization gas chromatography to obtain an estimate of oil content.

The procedure of extraction and cleanup is given in detail here, since in the problem of oil pollution gas chromatography results are comparable only if obtained in the same manner.

(1) Place 5 g of each dried composite sample into a clean 125 ml Erlenmeyer flask.

(2) Add 50 ml benzene-methanol azetrope (benzene 60.4%, methanol 39.6%) and 50 ml n-heptane.

(3) Allow to stand twenty-four hours and then place in an ultrosonic bath for fifteen minutes.

(4) After settling, decant heptane/azetrope solution into glass tubes and centrifuge.

Huggett, R. J., M. E. Bender, H. D. Sloan. 1971. "Mercury in sediments from three Virginia estuaries." Ches. Sc. 12:4. 280.

Huggett, R. J., M. E. Bender, H. D. Sloan. 1973. "Utilizing metal concentration relationships in the Eastern oyster (crasostrea virginica) to detect heavy metal pollution." Water Res. 7:451-460.

(5) Transfer supernatent liquid into 300 ml round-bottom flasks and evaporate on a rotary vacuum dryer until disappearance of the azetrope fraction (bottom layer disappears when temperature of flask increases to 260 C).

(6) Pass the partially evaporated samples through a chromatographic column consisting of activated alumina (AG-7, 100/200 mesh, 4.1% H_2O), eluted with 3 ml of heptane. Evaporate samples to 0.25 ml and inject portions into the gas chromatograph.

B. Petroleum Hydrocarbons in Fishes

The analytical procedure which was used to determine the kinds and amounts of petroleum hydrocarbons in fish is complex and time-consuming, and some of the techniques reported below were developed solely for this investigation.

The procedure reported below is that of a typical run on a fish sample of upstream white suckers taken from the Monocacy area (Figure 2), and each step was performed sequentially. Any variations in sample sizes and weights of products obtained with other fish samples (and spilled crankcase oil waste) are discussed in the Results and Discussion, page 48.

Samples were packed in dry ice and shipped in insulated chests. The samples were thawed to remove flesh for heavy metals analysis, then refrozen and kept in cold storage until analysis.

(1) General Laboratory Precautions

The following laboratory precautions were practiced to minimize error, contamination, and decomposition during the analysis of hydrocarbons:

a. Samples were stored in either a dark cabinet or in brown bottles capped with aluminum foil liners, since ultraviolet radiation is known to decompose polycyclic aromatic hydrocarbons.

b. The laboratory was equipped with General Electric F-40-G_0 yellow fluorescent lamps to minimize ultraviolet light.

c. Observations of fluorescent zones during chromatography, using a Gelman Camag ultraviolet lamp at 350 nanometers, were held to a minimum to avoid hydrocarbon decomposition.

d. Smoking was not permitted in the laboratory to avoid possible contamination of samples.

e. All glassware (and grinding/blending equipment) was detergent-washed, rinsed in water followed by acetone, and dried under an infrared lamp or in the atmosphere. It was further rinsed in fractionated benzene and dried under an infrared lamp prior to use.

(2) Solvent Purification

All solvents (except where specified) were purified by fractionation of 2.5 liter batches, under nitrogen, through a 22 x 2.3 (ID) cm column packed with cut glass tubing. The all-glass apparatus was assembled using ungreased ground joints and protected from the atmosphere with a tube of anhydrous calcium sulfate. The first 250 Ml forerun and last 250 Ml pot residue of each batch were discarded. Fractionated solvents were stored in metal foil-lined capped brown bottles. Ethyl ether used in column chromatography was glass-distilled from Burdick and Jackson Laboratories, Inc.

(3) Extraction of Oils from Fish

Materials used were fractionated benzene, Fisher B-245(see previous Solvent Purification Section); anhydrous magnesium sulfate, Fisher M-65, which was Soxhlet extracted forty-eight hours with fractionated benzene before use, and dried under an infrared lamp.

Blending and extraction procedures are as follows:

a. Grind two to three fish specimens with a standard meat grinder into a porcelain dish and mix with a spatula.

b. Weigh, to the nearest gram, about 500 g of ground fish into a one-quart stainless steel Waring blender, and partially blend.

c. Add 7% by weight of benzene for the purpose of aiding the grind, and blend until a "fish soup" after blending to determine the losses of volatiles.

d. Weigh the "fish soup" after blending to determine the losses of volatiles.

e. Weigh 250 g of "fish soup" into a beaker and immerse in ice.

f. Add 180 g of preextracted anhydrous magnesium sulfate and stir until a solid mixture is formed.

g. Regrind blend in a Waring blender to a powdery consistency (some lumpy material cannot be eliminated, however), to give a "fish powder".

h. Weigh approximately 100 g of "fish powder" sample into a Soxhlet thimble which has been previously extracted for forty-eight hours with benzene.

i. Extract "fish powder" for twenty-four hours in refluxing benzene.

j. Strip benzene extract of solvent at the water pump on a hot water bath using a rotary evaporator by trapping the benzene distillate in a filter flash assembly immersed in ice water, and save the fish oil residue.

k. Repeat steps (h) and (j) with a fresh fish powder sample and combine the oils obtained in step x.

Assuming the losses in volatile material from step (d) to be the added benzene, the fraction of fish in the fish "soup" can be calculated as:

$$\begin{array}{l}\text{fraction of}\\ \text{fish in}\\ \text{fish "soup"}\end{array} = \frac{\text{weight original ground fish}}{\text{final weight fish soup}}$$

The percent fish in the final "fish powder "is then calculated as:

$$\begin{array}{l}\text{\% fish in}\\ \text{fish + MgSO}_4\end{array} = \frac{\text{wt. fish soup x wt. fraction fish in fish "soup"}}{\text{wt. fish soup + wt. MgSO}_4}\,100$$

The extraction data for the samples processed are given in Appendix V-1.

(4) Saponification of Oil Extracts.

Materials used were 6N KOH (Fisher USP) in fractionated methanol; cyclohexane, Fisher C-556, fractionated; benzene, Fisher B-245, fractionated; sodium chloride, Fisher S-271; magnesium sulfate, Fisher M-65, preextracted forty-eight hours with fractionated benzene.

Saponification procedures are as follows:

a. Mix extracted oil with 6N potassium hydroxide and leave at room temperature for forty-eight hours.

b. Dilute mixture with water, transfer to a 500 ml separatory funnel, and extract twice with cyclohexane and twice with benzene. Combine extracts.

The separation of the layers in this step was difficult. The addition (and mixture) of solid sodium chloride in the separatory funnel for as long as twelve to sixteen hours helped to break the emulsions. In those cases where a clear cut separation of the layers could not be achieved, the top hydrocarbon layer was separated with a pipette so that a clear hydrocarbon extract devoid of interfacial material was obtained for the next step.

c. Wash hydrocarbon extract with about 25% its volume of 1N sulfuric acid (twice) and water (twice).

d. Dry extract over anhydrous sulfate and filter off the magnesium sulfate using a medium-porosity sintered glass funnel (Pyrex #36060) washed with benzene.

e. Evaporate extract leaving a viscous oil to be used for column chromatography.

The data, including volumes of 6N KOH, volumes of water and solvents used, etc., are given in Appendix V-2.

(5) Column Chromatography of Saponified Extracts.

Materials used were aluminum oxide (alumina), basic, Type E, (activity I), Brinkmann Instruments, Inc., without further purification; anhydrous magnesium sulfate, Fisher M-65, preextracted forty-eight hours with fractionated benzene; cyclohexane, Fisher C-556, fractionated; benzene, Fisher B-245, fractionated; ethyl ether, glass distilled, Burdick and Jackson Laboratories, Inc.; chromatographic column (Fisher Porter) 5.0 cm ID fitted with a fritted disk and stopcock, A. H. Thomas catalog Nos. 2726-Q82, -R20, -R83, -S42.

Chromatographic procedures are as follows:

a. Mix saponified extract with four times its weight of basic alumina, blanket with a little cyclohexane, and leave for forty-eight hours at room temperature.

b. Assemble chromatographic column (5.0 or 2.0 cm inside diameter) with a fritted glas disc and stopcock at its base, and partially fill with cyclohexane. Add alumina from the top, stir in the cyclohexane, and allow to settle. Add anhydrous magnesium sulfate equal to 10 percent of the weight of alumina, stir, and allow to settle.

c. Place slurry of alumina/sample/cyclohexane (from a) in the chromatographic column and open the stopcock to allow the cyclohexane to approach the level of the top of the sample (save eluate).

d. Collect the following three fractions from the column:

-- cyclohexane fraction
-- benzene fraction
-- 90:10 benzene; ethyl ether fraction

e. Strip cyclohexane fraction at the water pump on a hot water bath.

f. Combine benzene and benzene-ethyl ether fraction and strip solvent at the water pump.

g. Reserve the non-volatile hydrocarbon residues from (e) and (f) for infrared and gas chromatographic analysis.

The data for the column chromatographic step are given in Appendix V-3.

(6) Infrared and Gas Chromatographic Analysis

Infrared spectra of all hydrocarbons were determined as smears between salt plates on a Bausch and Lomb Schimadzu Spectronic 250 infrared spectrophotometer. After analysis, the samples were reisolated from the salt plates by washing with fractionated benzene. The benzene solvent was stripped at the water pump to leave the hydrocarbons which were subsequently analyzed by gas chromatography.

Gas chromatography of the cyclohexane eluate was performed on a Varian Aerograph Model 2720 using 7' x 1/8" 1.5 percent OV-17 on Chromosorb G 100/120 DMCS for the cyclohexane fraction. All runs were programmed from 50-293°C at 8°/min using N_2 carrier gas at 22 psig. Injector and detector temperatures were 216°C and 270°C, respectively.

Gas chromatography of the aromatic hydrocarbons from benzene-benzene/ethyl ether eluate was performed on the same instrument using a 7' x 1/8" 4.5 percent SE-52 on Chromosorb G 100/120 DMCS at 50-293° at 8°/min using N_2 carrier gas. For gas chromatography of hydrocarbons from benzene-benzene/ether fraction obtained from the Harrison Lake fish samples and standard hydrocarbon mixture, the isothermal hold period was set at 300°C.

The benzene-eluted compounds from column chromatography of the Harrison Lake samples were each treated with a known quantity of triphenylmethane just before gas chromatography.

The infrared spectra are given in Figs. 13-23, and gas chromatograms are given in Figs. 24-41. Gas chromatograms pertaining to Harrison Lake fish are shown in Figs. 42-47.

6. BIOLOGICAL ANALYSES OF RIVER BIOTA

A. Chlorophyll a

Chlorophyll a samples were filtered in the field on GF/C filters and shipped in darkened ice containers to the laboratory where they were frozen and kept darkened until analysis. They were analyzed by standard spectrophotometric techniques (Lorenzen, C. J., 1966 & 1967) that measure pigment fluorescence within two days of field collection. Since most petroleum products also emit fluorescence, tests were performed to determine if presence of oil in the river would bias chlorophyll a readings. Oil from the Berk Associates plant was added to three water samples (collected from an area not contaminated by the oil spill) at concentrations of .4 percent and compared to three controls lacking oil. Although total chlorophyll a levels were similar between treated and control samples, active and dead chlorophyll a concentrations in the oiled samples averaged 64% higher (7.4 as compared to 4.5 mg/l) and 32 percent lower (10.4 as compared to 15.3 mg/l), respectively, than in the controls. Thus, spectrophotometric techniques may tend to overestimate the ratio between live and dead pigments below the oil spill. This bias is probably minimal due to the relatively low oil levels found in the river (measured in ppm) as compared to the amounts added in these tests.

B. Zooplankton

Zooplankton samples were collected with a #12-mesh metered net (2-ft diameter), preserved in 10 percent formalin, and subsampled to determine organism abundance.

C. Benthic Macrofauna

Macrofauna were collected with a .25 ft^2 Ekman dredge, preserved in 10 percent formalin, and washed onto a 1.mm screen prior to separation. Organisms in the more important taxons were identified down to the generic level.

D. Bacteria

Sediment samples for bacteria analysis were placed in sterile petri dishes in the field and transported in ice to the laboratory where several decimal dilutions were prepared by placing 11 g of mud sample into 99 ml of sterile buffered dilution water. The mixture was

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Lorenzen, C. J. 1966. "Method for the Continuous Measurement of Invivo Chlorophyll Concentration," Deep Sea Research, Vol. 13, pp. 223-227.

Lorenzen, C. J. 1967. "Determination of Chlorophyll Pheo-Pigments: Spectrophotometric Equations," Limnol. Oceanography, 12:343-345.

shaken twenty-five times and transferred (11 ml) to each successive 99 ml dilution bottle. Bacteriological counting procedures were as follows:

(1) Standard plate count. Estimation of viable aerobic, mesophilic, heterotrophs was made by spreading 0.1 ml portions of diluted samples on plates of tryptone glucose extract agar using sterile glass rods. Colony counts were made after five days at 25°C.

(2) Hydrocarbon oxidizers. Bushnell-Haas medium was prepared from ingredients and solidified with 1.5 percent agar (Oxoid brand Ion-agar No. 2). B-H medium is a mineral-salts base without carbon source and supposedly does not support bacterial growth unless a suitable carbon source is added. For counts of hydrocarbon oxidizers, spread plates of suitable dilutions were prepared on B-H agar and inverted with 0.1 ml of kerosene added to the lid. In a few instances, additional plates were prepared, and 0.1 ml of sterile dodecane was pipetted to the surface of the inoculated, non-inverted plates.

(3) Casein hydrolyzers. Spread plates of nutrient agar containing 10 percent (v/v) of sterile skim milk were made, and colonies showing zones of clearing (hydrolysis) were counted.

(4) Amylolytic organisms. Nutrient agar containing 0.2 percent of soluble starch was used to prepare spread plates. After flooding with iodine solution, colonies surrounded by clear zones were counted.

(5) Fermentative bacteria. Tubes containing 10 ml of purple broth base (BBL) plus 0.5 percent glucose were inoculated in triplicate with 1.0 ml of appropriate dilutions. These showing acid production (yellow indicator) were scored positive and used to determine mpn values from standard tables.

(6) Sulfate reducing bacteria. From the initial 1:10 dilution of mud sample, 1.0 ml portions were transferred to 9 ml of sulfate reducer agar API (Difco) at 450°C in screwcapped tubes. Serial decimal dilutions were made in the molten agar. After twenty-one days at 25°C in an anaerobic jar, tubes showing blackening were scored positive and MPN values determined.

E. Dissolved Oxygen and Community Respiration

Oxygen measurements were taken throughout the twenty-four hour daily cycle and used to estimate gross primary productivity and community respiration according to the diurnal-curve method of Odum (1956). The single-curve modification was employed. Corrections for diffusion were obtained by assuming the coefficient of gas transfer (K) to be 2.0 $g/m^2/hr$ at 0 percent saturation (estimated from Odum's table 1). Community respiration was determined by extrapolating the diffusion-corrected hourly predawn oxygen decrease (measured in ppm) to the twenty-four hour daily cycle and multiplying by river depth. Gross primary production was calculated by measuring the area between the diffusion-corrected rate-of-change curve and a horizontal line drawn through the predawn hours and multiplying by river depth. Depth at both sampling stations was about 1 m.

F. Food Habits of Fishes

Fishes were captured by hook and line and net. Stomachs were extracted, slit along one surface to allow rapid preservation of contents, wrapped in gauze stripping, and shipped in 10 percent formalin to the laboratory.

7. OBSERVATIONS OF SHORE CLEANUP IMPACT AND EFFECTIVENESS

Cleanup operations were monitored by direct observation for the first five days and recommendations submitted on a daily basis during July, 1972. Hosing operations removed oil from sight but put it into the river where the effects where the effects may be more serious.

Booms properly and rapidly deployed in reaches of the river with currents less than 2 knots will.permit containment of the oil for pickup by vacuum trucks or other oil collection systems.

Burning of oil-covered debris and recovered oil was not considered judicious since burning releases lead and other heavy metals in their most harmful vapor form.

Pools of oil along the shore line were observed requiring cleanup since several were running into the river.

Odum, H. T. 1956. "Primary Production in Flowing Waters," Limno. Ocean. 1: 102-117.

RESULTS AND DISCUSSION

1. PROPERTIES OF SPILLED CRANKCASE OIL WASTE

The spilled oil had a specific gravity of 0.97. A sample of spilled crankcase oil waste (SCOW) collected from the riverbank near Unionville in July of 1972 contained 33 percent petroleum hydrocarbon, 51 percent water, 13 percent insoluble residue, and 3 percent water soluble remainder by difference. Direct distillation of the SCOW up to 185°C yielded approximately 0.5 percent organic volatile material.

Visual inspection of the spilled oil suggested that it contained mostly tars and aliphatics. The oil sample contained 48 percent aliphatic hydrocarbons and 4.5 percent aromatic hydrocarbons.

The spilled oil contained high concentrations of the heavy metals lead, zinc, cadmium, and copper (Table 2). An analysis of oil samples from the storage pits, conducted by the Environmental Protection Agency in 1971 (Table 3), also indicated the presence of heavy metals.

2. EFFECTS OF THE OIL SPILL ON VEGETATION

A. General

A survey, taken on 1 and 2 July 1972, of oiled riverbank areas from the spill site to Valley Forge revealed that trees along both banks of the Schuylkill River were extensively coated with spilled oil (Figure 5) to a height of approximately 20 to 25 feet above the normal river level (Figure 6) with the trees in the Douglassville area most heavily coated. No variation in oil thickness at different tree heights was noted. However, the upper, uncoated foliage did not show symptoms of damage.

The riverbank tree community had sustained considerable damage by the force of the river water which pushed the trees over and, in some cases, uprooted them. This type of mechanical damage occurred all along the river and was not related to the oil-coating problem. It was observed during an air survey on 1 July that the foliage of some uprooted trees in the river was trapping and collecting the floating oil. Since the foliage would probably release oil into the river over a period of weeks, it was recommended that these oil-coated and uprooted trees by removed to a disposal site.

TABLE 2 Constituents of Spilled Crankcase Oil Waste Collected Near Douglassville Bridge in July, 1972

HEAVY METALS[1]

Lead	16,300 ppm ± 6%
Zinc	1,960 ppm ± 2%
Cadmium	5.1 ppm ± 6%
Copper	87 ppm ± 2%

% Solids: 11.1%

HYDROCARBONS

Water	51%
Hydrocarbon Oil	33%
Insoluble Residue	13%
Water Soluble Remainder	3%

POLYCHLORINATED BIPHENYLS

Test: negative, sensitivity 0.5 ppm

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[1] Mean of replicate analyses.

TABLE 3 Heavy Metal Concentrations in Waste Crankcase Oil Samples Collected and Analyzed in 1971 by the U. S. Environmental Protection Agency

Element (mg/kg of oil)	Sample 14604	Sample 14612	Sample 14631	Sample 14634
Zinc	1,800	2,100	165	350
Cadmium	10	9	5	16
Arsenic	50	45	25	80
Boron	5	18	25	8
Phosphorous	50	1,700	970	950
Iron	2,500	2,200	128	96
Molybdenum	20	18	10	30
Manganese	58	63	5	64
Aluminum	430	560	85	66
Beryllium	0.1	0.1	0.05	0.1
Copper	210	190	18	41
Silver	1	0.8	0.5	2
Nickel	10	8	5	16
Cobalt	10	0.8	9.9	31
Lead	10,000	19,000	5,200	6,600
Chromium	16	28	3	10
Vanadium	22	18	22	48
Barium	360	740	24	1,600
Strontium	64	2.7	5.8	3.3

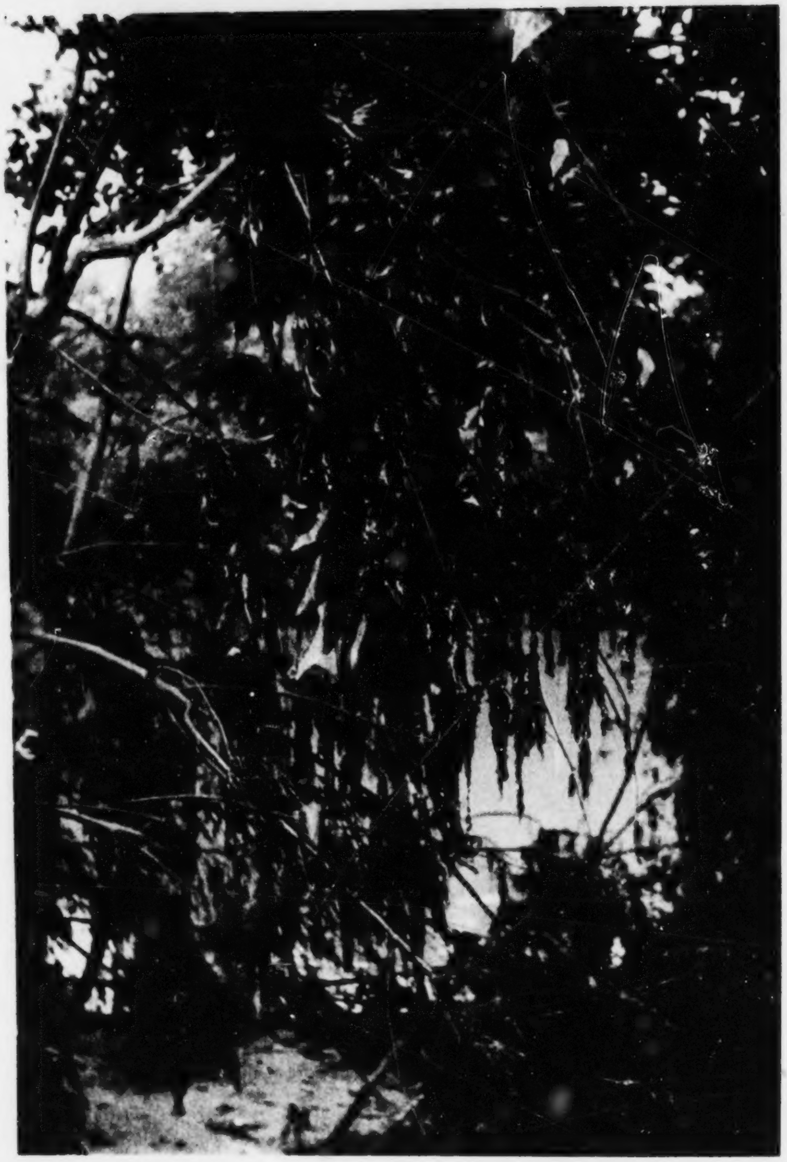


Figure 5 Extensively Oiled Riverbank Vegetation

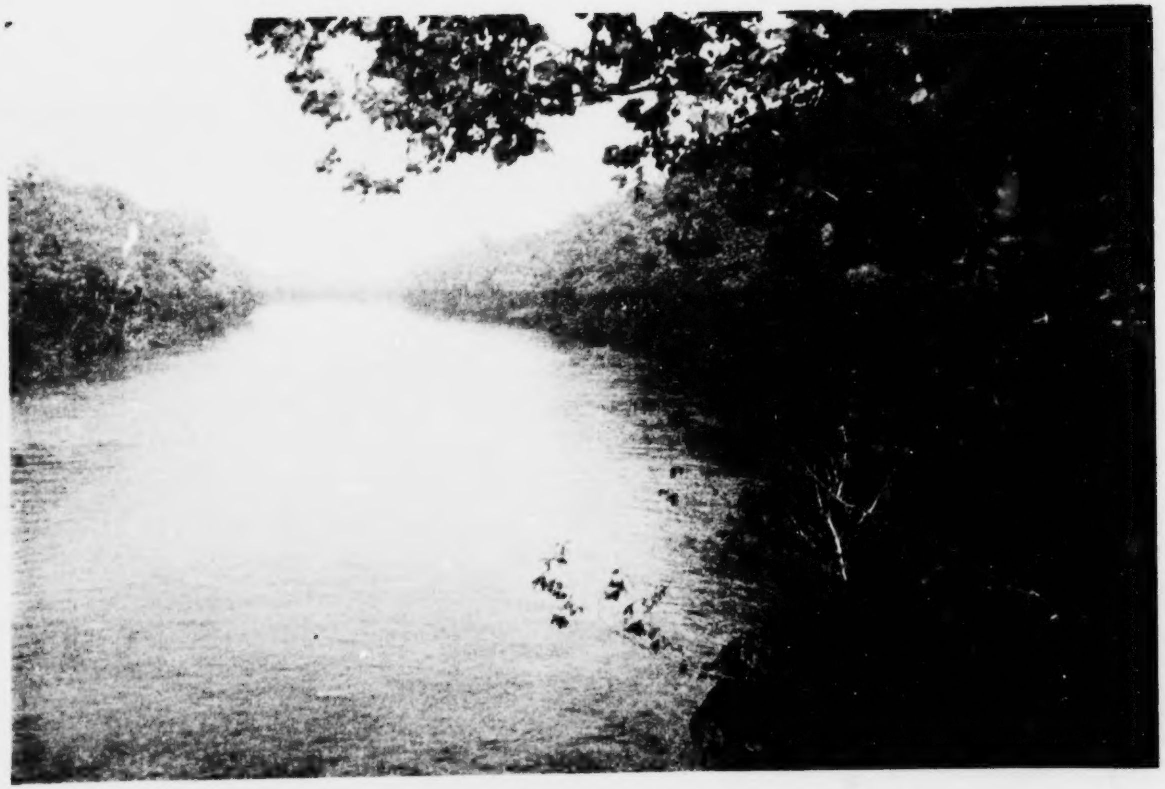


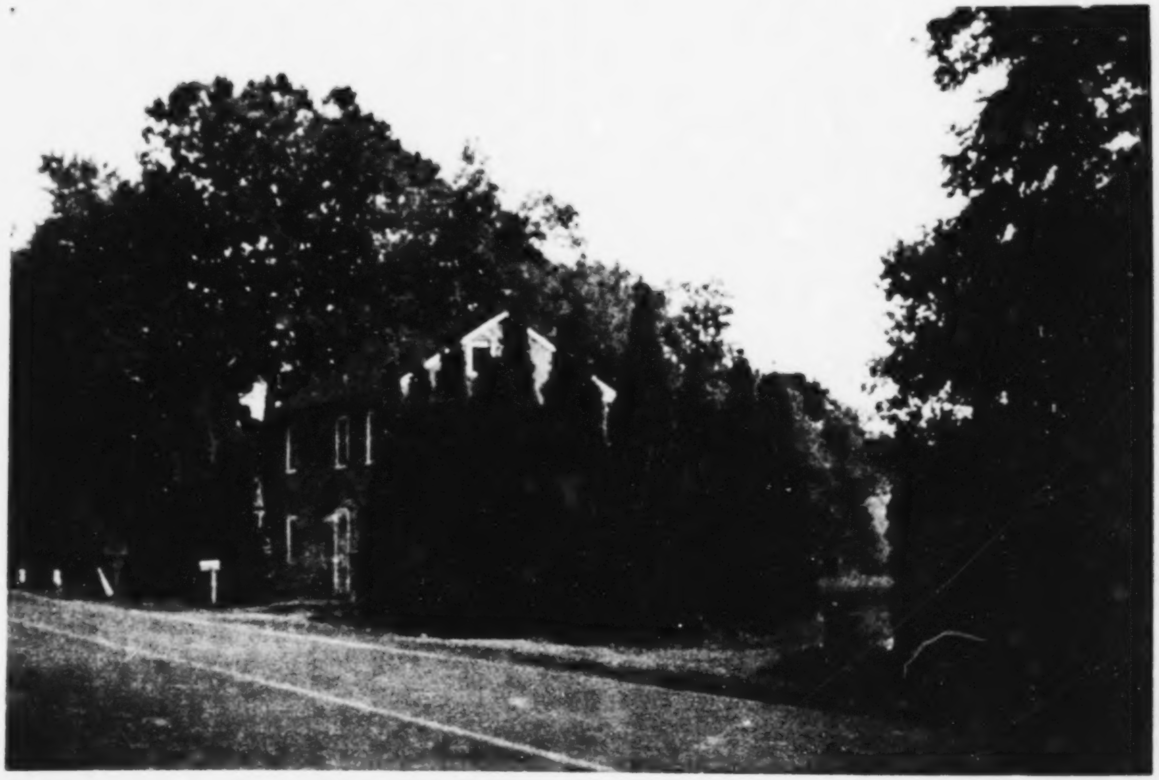
Figure 6. Oil-coated riverbank vegetation along the banks of the Schuylkill River in July, 1972

Many tree species at the Douglassville Bridge sampling station were developing new leaves from the oil-coated branches as early as 8 July 1972. This indicated that the growing points had not been killed by the oil and that biological recovery was progressing in spite of presence of oil on the soil, foliage, and trunks. Herbaceous plants on the riverbank were beginning to show signs of recovery.

A winter survey was made on 3 January 1973 of the trees along the riverbank at Douglassville Bridge, Unionville, Parker Ford, and other points to examine the terminal and lateral buds of several mixed stands of trees. Longitudinal and cross-section of buds and small twigs were made on the scene and examined for evidence of tissue necrosis. Internode lengths of the trees were also examined and compared to the previous season's growth. There was no evidence that the buds of the oil-soaked trees were dying nor was there any obvious indication of decreased growth rates. Dormant buds on the trees were plentiful and appeared to be normal. Some dead trees were still coated with oil. However, they were relatively few compared to the population of trees examined. Some trees had a few dead, oil-coated branches. It was expected that these dead branches would become infected with wood-rotting pathogenic fungi which would invade the main trunk and eventually kill the tree.

Additional checks on the recovery of the deciduous tree community were made during the spring and summer of 1973. The results of these surveys were basically the same. No unusual symptoms of permanent damage were found. During the summer survey, some dead branches were found; and there was evidence of invasion by wood-rotting fungi. In general, however, the trees and herbaceous species in affected areas showed excellent recovery.

There was one exception to the remarkable recovery of the tree community. Evergreens and other ornamental species in the yards of private residences along the river had been severely damaged. Damaged trees included conifers, such as pines, hemlocks, firs, and spruces. Other evergreen species that suffered damage were yews and junipers (Figures 7 and 8). The growing pattern of evergreens is much different than that of the deciduous trees. Deciduous trees were able to shed their damaged leaves. In contrast, conifers shed their needles very slowly and are unable to rid themselves of damaged tissue that can cause harm to affected branches. Many oil-soaked evergreens in private residences have lost their aesthetic value and are probably irreparably damaged.



Oil
Level →

Figure 7. Oil-coated ornamental evergreens 10 days after the oil spill

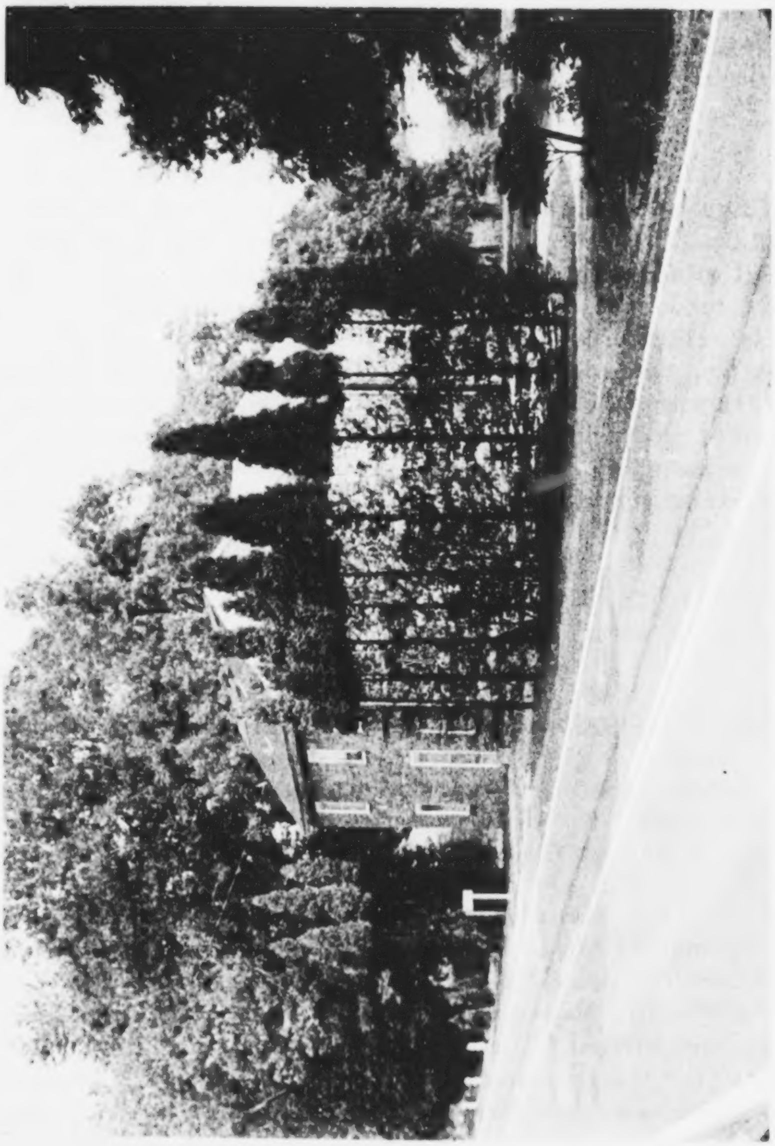


Figure 8. Oiled evergreens 1 year after the oil spill

B. Penetration of Oil Through Bark

Freehand, stained sections of oak, maple, and sycamore tree bark revealed that oil which was tenaciously attached to the outer bark did not appear to penetrate beneath the surface to any great degree (Figure 9). Penetration was probably prevented by the cork layer. Oak and maple have relatively thick cork layers compared to sycamore. However, the bark of sycamore is exfoliative and falls off in time.

C. Heavy Metals in Tree Leaves

Plants have been shown to accumulate metals from their surroundings. One potential long-term effect of this spill was viewed as the uptake of toxic concentrations of heavy metals from the oil-coated soil or through the bark. Thus, a study of heavy metal accumulation was conducted. Based on the analyses of the oil (Tables 2 and 3), the metals selected for study were lead, zinc, cadmium, and copper. The study was designed to detect trends of abnormally high accumulations of heavy metals derived from the oil which may have correlated with any observed symptoms of phytotoxicity. Sampling was concentrated on those species representative of the mixed deciduous forest along the banks of the Schuylkill.

Data from the heavy metals analysis of the leaves collected at Monocacy, Douglassville, and Parker Ford in May, 1973, is presented in Tables 4, 5, and 6.

A non-parametric sign test (Snedecor and Cochran 1967) was applied to the pooled data of seven pairs of species at Monocacy Farm and Douglassville Bridge. Lead values were significantly greater at the 95 percent confidence level in affected leaves from the Douglassville Bridge area. The levels of other metals at oiled and control stations were not significantly different.

The statistically significant difference in lead concentrations between Monocacy Farm and Douglassville Bridge is probably not important in terms of well-being of the trees. Considerably higher amounts of lead are known to occur in many plant species. Smith (1973) reported difficulty in establishing "normal" levels of lead even after sampling trees in relatively unpolluted areas and comparing values to published concentrations obtained from similar areas. He

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Snedecor, G. W. , and W. G. Cochran. 1967. Statistical methods: Iowa State University Press, Ames, Iowa. 593 p.

Smith, W. H. 1973. "Metal contamination of urban woody plants." Envir. Sci. Tech. 7:631-636.

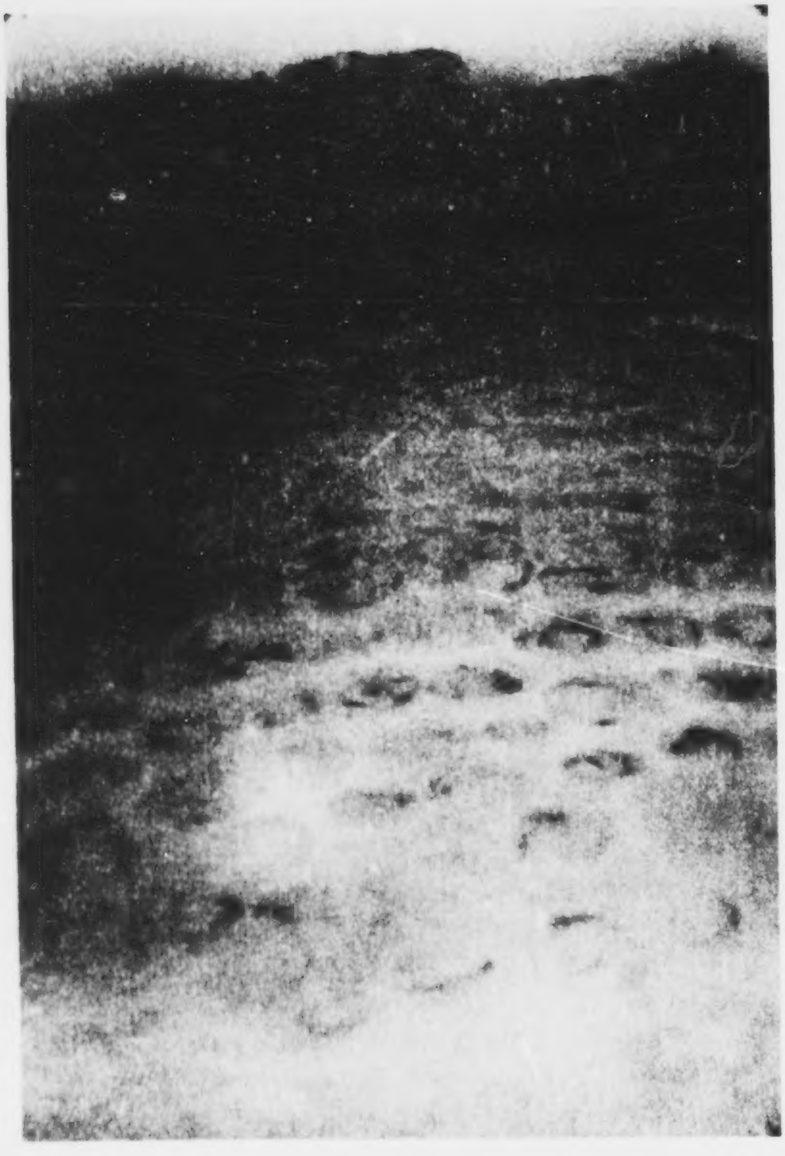

Figure 9. Cross-section of oiled oak bark magnified 613X

TABLE 4 Heavy Metal Concentrations in Tree Leaves Collected from Monocacy Farm in May, 1973

Species	No. of Trees Sampled	Heavy Metal Concentration (ppm)[1]			
		Lead	Zinc	Cadmium	Copper
Maple	12	5.0	26.0	*	0.4
Oak	7	6.0	28.0	*	0.4
Oak	7	5.0	21.0	*	0.6
Sassafras	6	3.0	29.0	*	0.5
Sycamore	8	4.0	20.0	0.8	0.5
Elm	4	5.0	73.0	*	0.8
Black Walnut	3	6.0	24.0	*	0.5

[1] **Mean of replicate analyses for each element from the pooled sample.**

*Less than 0.5 ppm.

TABLE 5 Heavy Metal Concentration in Tree Leaves Collected Near the Douglassville Bridge in May, 1973

Species	No. of Trees Sampled	Heavy Metal Concentration (ppm)[1]			
		Lead	Zinc	Cadmium	Copper
Maple	12	11.0	32.0	*	0.4
Oak	6	8.0	32.0	*	0.8
Oak	1	9.0	25.0	*	0.8
Sassafras	3	4.0	25.0	*	0.6
Sycamore	1	6.0	20.0	*	0.8
Elm	8	10.0	25.0	*	0.4
Black Walnut	7	8.0	27.0	*	0.6

[1] Mean of replicate analyses for each element from the pooled sample.

*Less than 0.5 ppm.

TABLE 6 Heavy Metal Concentrations in Tree Leaves Collected Near the Pottstown Bridge in May, 1973

		Heavy Metal Concentration (ppm)[1]			
Species	No. of Trees Sampled	Lead	Zinc	Cadmium	Copper
Oak	4	6.0	22.0	*	0.5
Oak	2	6.0	24.0	*	0.4
Sycamore	5	5.0	30.0	*	0.6

[1] Mean of replicate analyses for each element from the pooled sample.

*Less than 0.5 ppm.

cited literature describing lead concentrations in unpolluted environments as approximating 1 ppm. Baumhardt and Welch (1972) reported lead concentrations from 3.6 to 27.6 ppm in symptomless corn leaves. Concentrations of lead in grasses along two highways ranged from 20 to 60 ppm (Chow 1970). Warren and Delavault (in Campbell and Mergard 1972) suggested that "normal" lead concentrations be considered to be 0.1 to 2.5 ppm. On the other hand, Mortvedt *et al* (1972) reported apparently healthy radish plants growing at concentrations of 2.3 ppm to 12,000 ppm lead. Lead levels in trees along the Schuylkill are not abnormally higher than concentrations reported in other investigations (Chapman 1966, Gauch 1972, Lounamaa 1956, Smith 1973). Similarly, Jones's (in Montvedt *et al* 1972) normal range for zinc is 25 to 150 ppm with zinc toxicity not occurring below 400 ppm.

3. PHYSICAL AND CHEMICAL PARAMETERS OF SCHUYLKILL RIVER WATER

Water temperature at Monocacy and Parker Ford Bridges (Appendix I-1) ranged from 21°C to 28°C during July, 1972. Oxygen levels (Appendix I-1) varied from lows of around 4.5 to 7.0 ppm in the

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Baumhardt, G. R., and L. F. Welch. 1972. "Lead Uptake and Corn Growth with Soil-Applied Lead," *J. Envir. Qual*. 1:92-94.

Chow, T. J. 1970. "Lead Accumulation in Roadside Soil and Grass," *Nature* 225:295-296.

Campbell, I. R., and E. G. Mergard. 1972. *Biological Aspects of Lead: An Annotated Bibliography, Part I and Part II.* E.P.A. Publication No. AP-104.

Mortvedt, J. J., P. M. Giordano, and W. L. Lindsay (eds). 1972. *Micronutrients in Agriculture,* Soil Soc. Amer., Inc., Madison, Wisconsin. 666p.

Chapman, H. D. (ed.). 1966. *Diagnostic Criteria for Plants and Soils,* Div. Agr. Sci., University of California, Berkeley. 793 p.

Gauch, H. G. 1972. *Inorganic Plant Nutrition,* Dowden, Hutchinson, and Ross, Inc., Stroudsberg, Pa. 488p.

Lounamaa, J. 1956. "Trace Elements in Plants Growing Wild on Different Rocks in Finland," Ann. Bot. Soc. *Vanamo* 29:1-196.

Smith, W. H. 1973. "Metal Contamination of Urban Woody Plants," *Envir. Sci. Tech.* 7:631-636.

early morning to 5.5 to 8.0 ppm (about 62 to 91 percent saturation at 22°C) during midday. No differences were noted between upstream and downstream stations.

Alkalinity (Appendix I-2) ranged from 50 to 84 ppm with no apparent differences among upstream and downstream stations. Normal alkalinity in fresh water rivers and streams is about 0 to 200 ppm.

Daytime hydrogen-ion concentrations in July and August, 1972, (Appendix I-3) were 7.0 to 7.8 with maximum values usually occurring at the Valley Forge Bridge station. The presence of the highest values at Valley Forge suggests a downstream increase in primary productivity that is characteristic of many streams and rivers.

Biochemical oxygen demand (BOD) measurements taken during the summer of 1972 (Appendix I-2) ranged from 0.4 to 4.2 ppm. Highest levels were usually observed in the Douglassville Bridge - Parker Ford Bridge length of the river (0.7 to 11.7 miles below the oil spill).

Chemical oxygen demand (Appendix I-2) was between 5.38 to 15.44 during July and August, 1972. Maximum COD usually occurred in the length of the river between Douglassville Bridge and Spring City Bridge stations (0.7 to 16.4 miles below the oil spill).

4. CONCENTRATIONS OF METALS IN SCHUYLKILL RIVER WATER

Lead and zinc levels were generally highest directly below the oil spill (Douglassville-Parker Ford Bridge stations) until about mid-July, 1972 (Appendix II-1). Concentrations had dropped to background levels during the remainder of July. An increase in concentration was noted in August at Parker Ford. This trend is shown for lead in Figure 10. No differences in copper or cadmium levels were noted among stations sampled (Appendix II-1).

5. HEAVY METALS IN SEDIMENTS

Sediments in the Schuylkill River were analyzed for lead, zinc, cadmium, and copper during the summer of 1972. During November of 1972 sediments were analyzed for lead, zinc, cadmium, copper, and mercury.

Data from the summer of 1972 is presented in Appendix II-2. The summer 1972 survey was conducted to determine if there were areas of oil or metals contamination from the spill. No such areas were found. The winter 1972 sampling was concentrated in areas where sediment deposition was expected.

FIGURE 10. CONCENTRATIONS OF LEAD IN SCHUYLKILL RIVER WATER FROM JULY 3 TO AUGUST 4 1972

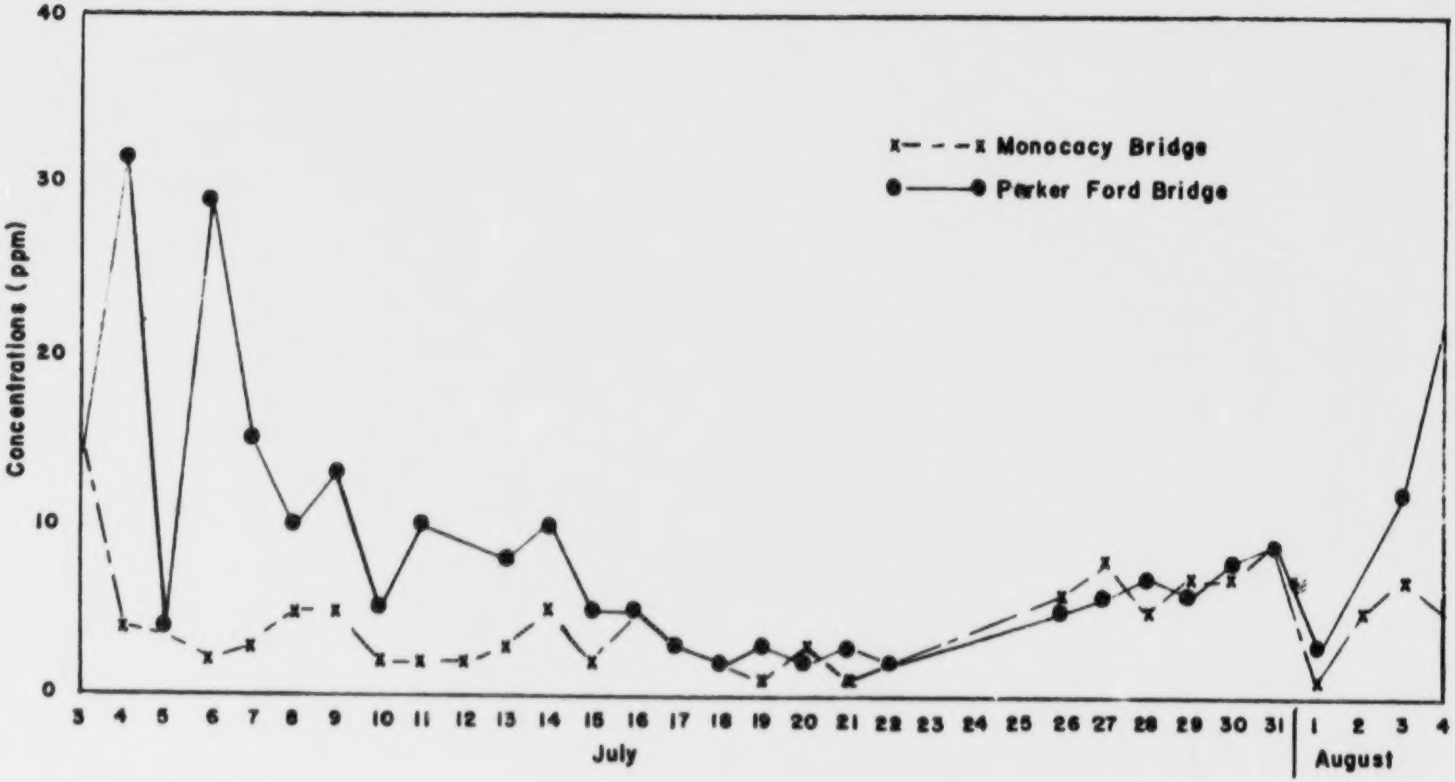
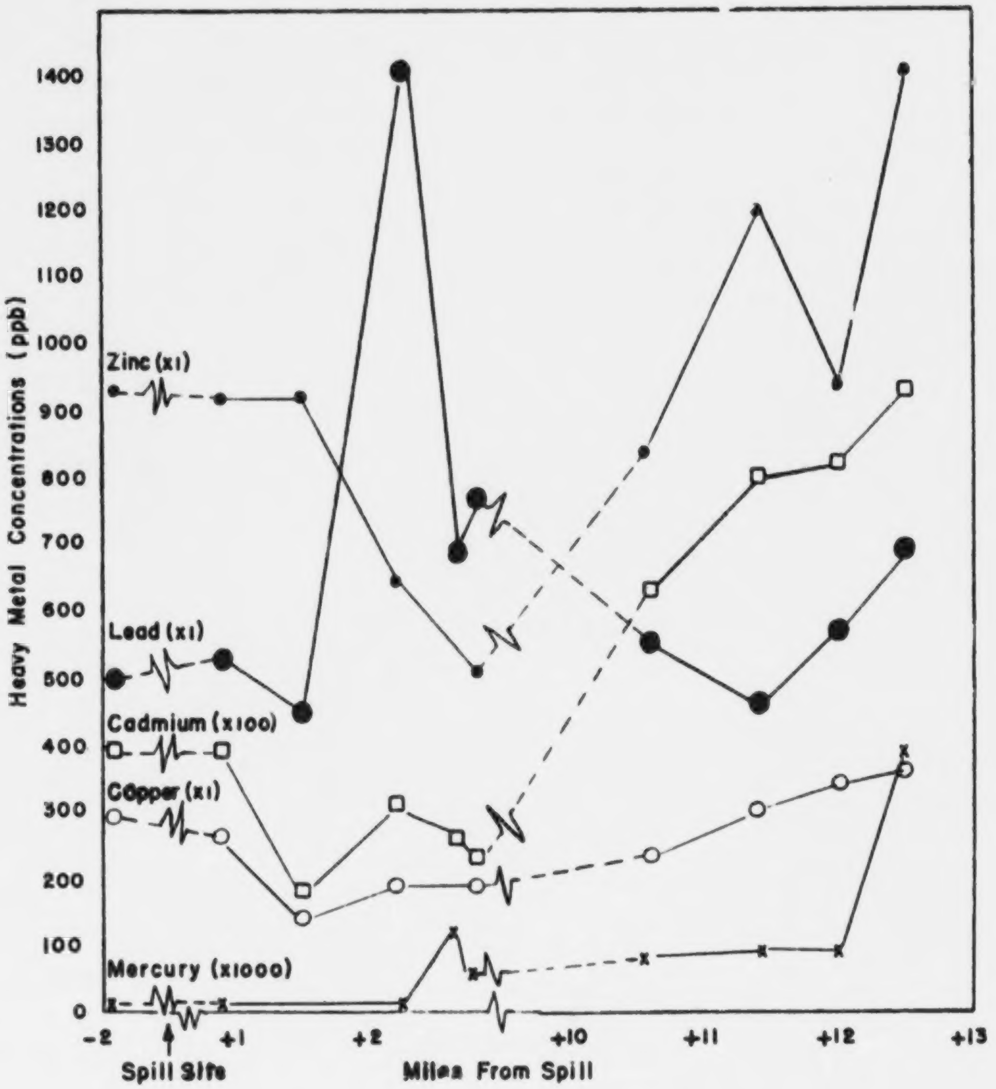


FIGURE 11. CONCENTRATIONS OF LEAD, ZINC, CADMIUM, COPPER AND MERCURY IN SCHUYLKILL RIVER SEDIMENTS COLLECTED IN NOVEMBER 1972



Data from the winter analyses is presented in Figure 11. The existence of many possible sources of pollution in the river between Douglassville and Parker Ford preclude assignment of the spill as the cause of the increased metals levels. Data from the November, 1972, analyses are tabulated in Appendix II-3).

Concentrations of all heavy metals were analyzed by "t" tests, or modifications of this procedure (Guenther, 1964) if heterogeneity of variances existed between samples, to determine if levels below the oil spill were greater than those observed in the Monocacy area. Only lead levels were significantly higher below the spill. The calculated t value was 3.71 as compared to a tabled value of 2.05 at the .95 confidence level extrapolated to 4.5 degrees of freedom. However, the significance was due to one extremely high lead level (1,400 ppm) observed below the spill.

Table 7 compares concentrations of lead, zinc, and copper in the Schuylkill with concentrations of the same metals reported by Houser (1972) in the Potomac River.

TABLE 7 Comparison of Metals in Schuylkill River and Potomac River Sediments

	Schuylkill	Potomac
Lead (ppm)	619.0	52.7
Zinc (ppm)	823.0	348.1
Copper (ppm)	234.1	70.2

Concentrations of these metals in the Schuylkill are significantly higher. It is realized that the Potomac is estuarine while the Schuylkill is fresh water. However, data presented by Hugget, et al (1972), for fresh water portions of the Rappahannock also suggest that

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Guenther, W. C. 1964. Analysis of Variance, Prentiss-Hall, Inc., New Jersey. 23 p.

Huggett, R. J., M. E. Bender, H. D. Slone. 1972. Final Report to the Corps of Engineers, Norfolk Dist. Analysis of dredge spoils from the James and Elizabeth Rivers.

the Schuylkill has unusually high background levels of heavy metal pollution. Levels of zinc and copper in the Schuylkill at the control (Monocacy) site are ten times higher than in the Rappahannock.

6. PETROLEUM HYDROCARBONS IN SCHUYLKILL RIVER SEDIMENTS

Gas chromatograms of oil from sediment composites collected in November, 1972, from above and below the spill (Appendix III-1 through III-12) show very high unresolved backgrounds.

The relative amounts of petroleum hydrocarbons in the sediment composites were computed using data on instrument attenuations, volumns injected, and the areas under the chromatograms. Relative concentrations at downstream stations as compared to Monocacy (control station) are shown in Figure 12. The underlying assumption was that hydrocarbons in the unresolved backgrounds of each chromatogram were of similar nature. In general, downstream stations show a much higher concentration of petroleum hydrocarbons than the upstream control stations. Levels were especially high directly below the oil spill. However, the upstream control stations exhibited the same types of oils, although at lower concentrations, as observed at the other stations.

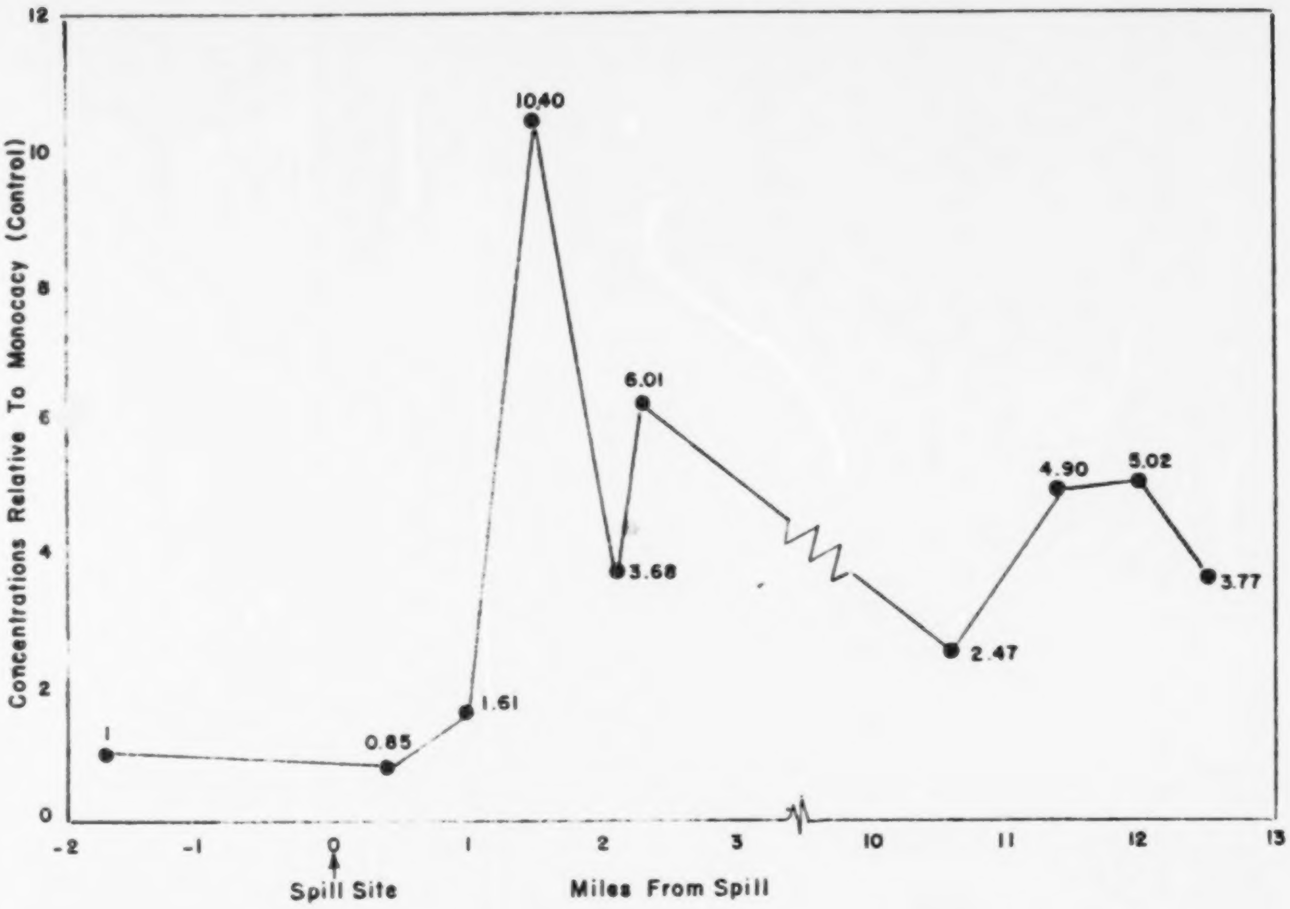
One subsample of a composite collected 1.7 miles below the spill was highly contaminated with oil, as evidenced by smell and visible sheen when mixed with water. Since the sample apparently contained the most oil, it was extracted and analyzed separately (Appendix III-5). By comparing this with the other analyses, it was noted that it contained twenty-five times as much oil as the control composite.

7. HEAVY METALS IN BENTHIC MACROFAUNA AND FISHES

Lead concentrations in mixed samples of Diptera larvae and Oligochaeta worms (mostly Tubifex) collected at benthos sampling station D-2 were a factor of 3-7 higher than samples taken above the oil spill (Appendix IV-1). Other metals exhibited no noticeable differences.

Levels of metals in fishes collected above and below the spill are presented in Appendices IV-2, IV-7. No significant differences due to the oil spill can be detected.

FIGURE 12. RELATIVE CONCENTRATIONS OF PETROLEUM HYDROCARBONS IN SCHUYLKILL RIVER SEDIMENTS COLLECTED IN NOVEMBER 1972



The extensive use of Diptera larvae as food by several species of fish (Appendix V-1) suggested that this food link could serve as a pathway by which metals could be accumulated in the fishes.

8. PETROLEUM HYDROCARBONS IN FISHES

The overall sequential analytical procedure used to search for the possible presence of petroleum hydrocarbon residues in fish is given in the Materials & Methods Section, page 20, and is diagrammed below:

WHOLE FISH

↓
1) grind in meat grinder.
2) blend in a Waring blender with 7.4% by weight of benzene,

"FISH SOUP"

↓
blend in a Waring blender with approximately 70% weight percent of anhydrous magnesium sulfate,

"FISH POWDER"

↓
1) Soxhlet extract 24 hours with refluxing benzene,
2) evaporate benzene,

EXTRACTED OIL (Appendix V-1, V-4)

↓
1) saponify oil in 6N methanolic KOH 48 hours at room temperature,
2) dilute with water and extract with cyclohexane and then with benzene (simple extraction),
3) wash the combined organic extracts with 1N H_2SO_4, dry, and evaporate solvent,

TOTAL HYDROCARBONS FROM SAPONIFICATION
(Appendix V-2, V-4)

(Continued)

TOTAL HYDROCARBONS FROM SAPONIFICATION (Continued from previous page)

1) apply to a basic alumina column for column chromatography,
2) elute with cyclohexane, leaving any fluorescent material on the column,
3) elute the fluorescent material
   i. with benzene followed by
   ii. 90/10 benzene/ethyl ether
   combine i) and ii),
4) evaporate solvent from the above two fractions

A) CYCLOHEXANE-ELUTED ALIPHATIC HYDROCARBONS (VERY WEAKLY FLUORESCENT) (see Appendix V-3, V-5)

1) infrared analysis
2) flame ionization GC analysis

IRs: Figs. 14-16
GCs: Figs. 26-29

IR = Infrared spectrum

B) BENZENE-BENZENE/ETHER-ELUTED AROMATIC HYDROCARBONS (STRONGLY FLUORESCENT)(see Appendix V-3, V-5)

1) infrared analysis
2) flame ionization GC analysis

IRs: Figs. 17-20
GCs: Figs. 30-33, 42, 46-47

GC = Gas Chromatogram

This procedure was applied to two sets of fish samples:

1) fish obtained from the Schuylkill River in July, 1973, in the region of the oil spill,

2) fish (presumably free of oil contamination) from Harrison Lake National Fish Hatchery, designated in this report as "HLFH" fish (see Subsection J, p. 86). In order to test the above analytical procedure, some "HLFH" samples were deliberately tainted with known amounts of polycyclic aromatic hydrocarbons in the initial blending step of the analysis, and finally the composite benzene-benzene/ether fraction from column chromatography was analyzed by GC.

The procedure, with some modification, was also applied to a sample of the spilled crankcase oil waste (SCOW), collected from the river in July, 1972. The GCs and IR spectra from this analysis, after column chromatography, are listed:

IR cyclohexane fraction: Fig. 13

IR benzene and benzene/ether fractions: Figs. 21-22

GC cyclohexane fraction (SCOW): Fig. 24

GC benzene/ether fraction (SCOW): Fig. 25

The above procedure was adopted because it combined the merits of published procedures and provided as much information as possible in the fewest analytical steps. These steps included:

1) separation of the benzene soluble oils from the fish

2) separation of the hydrocarbons from these extracted oils

3) separation of the hydrocarbons into two classes,

    i) the saturated aliphatic hydrocarbons, and
    ii) the polycyclic aromatic hydrocarbons

A similar type procedure was applied to the spilled crankcase oil waste (SCOW) to determine if any intelligible comparisons could be made between the hydrocarbons isolated from the fish *vs.* those isolated from SCOW.

The polycyclic aromatic hydrocarbons were of special interest in view of the known carcinogenic properties of some of these compounds. The notable early work of Cahnmann and Kuratsune (1957) describes the isolation and identification of these polycyclic aromatics in oysters which were taken from waters slightly contaminated by oil pollution. Their procedure involved a direct liquid-liquid extraction step on 5 kg of shucked oysters blended in methanol followed by saponification of the extract with methanolic potassium hydroxide. About

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Cahnmann, H. and M. Kuratsune. 1957. "Determination of Polycyclic Aromatic Hydrocarbons in Oysters Collected in Polluted Water," *Anal. Chem.* 29:1312.

twenty-one chromatographic columns were prepared using various adsorbents to isolate the polycyclic aromatics, many of which were identified by their characteristic ultraviolet absorption spectra. A list of these polycyclic aromatics appears in Fig. 34. This procedure applied to fish in the Schuylkill River would be very time-consuming and might limit the number of fish samples which could be examined.

On the other hand, facile and rapid methods of analysis such as direct gas chromatography on oils extracted from fish (or on SCOW) would render little conclusive information due to the extreme chemical complexity of any petroleum product. The suspected waste oil is theoretically able to be comprised of multi-thousands of hydrocarbons.

However, it should be noted that the work of Zafiriou, Blumer, and Myers (1972) provided "fingerprint" gas chromatographic comparisons of spilled crude oils with crudes from the spill source and were able to correlate them in many cases.

The examination of kerosene-like materials in the Australian mullet was pursued by Connell (1971), and the procedure included extraction of fish flesh with ethyl ether followed by steam distillation to separate the steam volatile hydrocarbons. The isolated hydrocarbons were subjected to gas chromatography, and the chromatograms compared to the chromatograms from oily river sediments and commercial kerosene. Similar studies were conducted on edible shellfish by Blumer, Souza, and Sass (1970) in which shucked shellfish were extracted with refluxing methanol, and the methanol extracts (and solids precipitated) extracted with pentane. Further separations were achieved with column chromatography followed by fingerprint gas chromatography. Comparison of the chromatograms obtained with those of a No. 2 fuel oil (accidentally spilled in the area before shellfish examination) revealed similarities in some cases.

Zarifiou, O., M. Blumer, and J. Myers. 1972. Correlation of Oils and Oil Products by Gas Chromatography. National Technical Information Service Report PB-211-337 UNPUBLISHED MANUSCRIPT.

Connell, D. W. 1971. "Kerosene-like Tainting in the Australian Mullet," Marine Pollution Bulletin, 12 (2): 188.

Blumer, M., G. Souza, and J. Sass. 1970. "Hydrocarbon Pollution of Edible Shellfish by an Oil Spill," Biol. 5:195.

In the present study of the spill in the Schuylkill River, the material spilled might well be composed primarily of a complex mixture of hydrocarbon materials. However, the material spilled was the waste product from the rerefining of waste crankcase oil. Thus, the expected tarry and intractible residues would undoubtedly differ in composition from a crude oil or a given kerosene fraction.

A. Blending and Extraction of Fish Samples (and SCOW)

The above published procedures for extracting oils from fish (and SCOW) may not be applicable to the present problem. For example, steam distillation of ether extracts from Schuylkill River fish may separate hydrocarbons; but the suspected contaminating material (SCOW) might be composed of high molecular weight hydrocarbons of low-vapor pressure. Because of the low-steam volatility of high molecular weight hydrocarbons, separation of these materials by this technique will be incomplete.

The blending of Schuylkill River fish with magnesium sulfate and subsequent Soxhlet extraction of the fish powder with refluxing benzene is a modification of a procedure published by the Patuxent Wildlife Research Center. In this process, fowl were ground and blended with anhydrous sodium sulfate, and the resulting free-flowing powder was subsequently extracted with refluxing petroleum ether. The use of anhydrous sodium sulfate failed with Schuylkill River fish, because the refluxing benzene resulted in liberation of water from the sample which clogged the flush tube in the Soxhlet apparatus completely inhibiting the extraction process.

The use of benzene vs. pentane or petroleum ether as an extracting solvent was preferred due to the known insolubility (or partial solubility) of some polycyclic aromatics in these solvents.

The essential data from the extraction are outlined in Appendix V-1 and the process is described on page 20. Some heat was developed in the blending process, and corrections were made for weight losses due to evaporation. Thus, the column labelled "Actual Sample Extracted" in Appendix V-1 represents a corrected value. The selection of twenty-four hours reflux time was based on weight studies of the amount of organic material extracted vs. time. These studies revealed that all the organic material was extracted in eighteen hours. The weight percent of the total oil extracted, based on weight of starting fish, varied from 2.8 to 5.9 percent. The oils extracted from HLFH fish samples on forty-eight hours benzene extraction gave variations ranging from 4.9 to 7.2 percent (Appendix V-4).

B. Saponification

The purpose of the saponification step was to further refine the fish oil obtained from the extraction step by converting the relatively non-polar materials (e.g., fat or lipid) to relatively polar materials (fatty acid salts and glycerol).

These polar and water soluble products can then be more easily separated in the next steps. The polar compounds were removed in the extraction of the water-diluted saponification mixture with hydrocarbon solvent followed by column chromatography. Other organic compounds that may be present such as aldehydes, organic acids, ketones, esters, and proteins are also sensitive to treatment with methanolic potassium hydroxide, but hydrocarbons in general are inert. A saponification step was used by Cahnmann and Kuratsune (1957) in their determination of polycyclic aromatic hydrocarbons in oysters.

The percent recoveries of oil from the saponification step varied from 17.8 percent in the downstream brown bullhead sample to 64.3 percent in the upstream crappie sample, based on the oils obtained from the original extraction (Appendix V-2).

The saponification step was the most difficult step in the analysis. Samples emulsified badly on extraction of the diluted saponification mixture with cyclohexane and benzene. The separation of layers was accomplished to some extent by the addition of solid sodium chloride. Even with the addition of salt, the clean-cut separation of layers, devoid of interfacial material, was not achieved. Sometimes the interface was not well defined. Despite these difficulties, clean organic layers containing the sought-after hydrocarbons devoid of interfacial material were separated. It is possible, however, that some of the hydrocarbon material was left behind in the interfaces.

Another difficulty was the gelation of some of the cyclohexane/benzene extracts after separation from the aqueous saponification mixture. The upstream brown bullhead extract gelled very badly after magnesium sulfate filtration. The gel completely clogged the chromatographic column in the next step of the analysis. Thus, the analysis for upstream brown bullheads had to be abandoned. During the analysis of the downstream crappies, gelation occurred before the filtration through magnesium sulfate, which increased the time required to perform the normally simple laboratory operation.

Cahnmann, H. and M. Kuratsune. 1957. "Determination of Polycyclic Aromatic Hydrocarbons in Oysters Collected in Polluted Water," Anal. Chem. 29:1312.

The apparent high yields of oil from the upstream crappies seemed to be largely a gel-like material, which was not revealed until the column chromatographic step. Then only plastic, brittle, gel-like materials were eluted from the column, as opposed to the oils usually observed, and these could not be analyzed.

The spilled crankcase oil waste extract was saponified to eliminate any interfering acidic substances. All saponification data are contained in Appendix V-2.

C. Column Chromatography

The purpose of this step was to separate the hydrocarbons from other polar materials and also to separate the aliphatic from the aromatic hydrocarbons for analysis by infrared and gas chromatography.

The three principal eluting solvents which were used, in sequence, were cyclohexane, benzene, and 90/10 benzene/ethyl ether. The last two eluates were combined to give a benzene-benzene/ether fraction. The principal criteria for the volumes of eluting solvents used was the observation of fluorescent material on the alumina column. Thus, the cyclohexane fraction was largely free of fluorescent material while the benzene-benzene/ether fractions were heavily fluorescent. Not all fluorescent material was eluted from the alumina column even when using a benzene/ethyl ether solvent combination.

The column chromatographic data are given in Appendix V-3. The upstream crappies, eluted only solid gels, while the chromatographic columns of the upstream brown bullhead became so badly clogged no solvent would pass through it, even under pressure. Consequently, these analyses were abandoned.

Except for the upstream brown bullheads, all column loadings were in excess of 33:1 alumina:oil sample. The lowest column loading (20:1 alumina: oil sample) was used for the badly clogging upstream brown bullhead samples.

Column chromatography data for downstream and upstream suckers are compared in Appendix V-3. Here the percent solids recovered based on starting material is 1.8 vs. 0.77 for cyclohexane eluates and 1.1 vs. 0.48 for benzene and benzene/ethyl ether eluates in downstream and upstream suckers, respectively.

D. Infrared Analysis

Infrared analyses (as smears between salt plates) were performed on all materials from column chromatography except for the upstream brown bullheads, the upstream crappies and the cyclohexane fraction from the downstream crappies. Analyses were abandoned if there was insufficient sample for a suitable spectrum. After spectral analysis, the samples were recovered by solvent washing from the salt plates and analyzed by gas chromatography.

The infrared spectra of all cyclohexane fractions, Figs. 13-16, from column chromatography were essentially identical and showed the predominant presence of aliphatic hydrocarbons both in the waste oil and fish. There were some small unidentified peaks from 12.2 to 13.8 μ in the spectrum from an unusually thick sample of downstream brown bullheads.

All spectra of the benzene + benzene/ethyl ether fractions from fishes, Figs. 17-20, were essentially identical and are strongly indicative of aromatic hydrocarbons. A relatively small amount of hydrocarbon residue was recovered from the downstream crappies during the extraction, saponification, and column chromatography steps. Therefore, the infrared spectra of this sample was not as clear as the others and minor differences were not discernible.

The spectrum for the "benzene" fraction of SCOW from column chromatography is given in Fig. 21. While it was indicative of aromatic hydrocarbons, its peaks were not as well resolved as the corresponding spectra of fish, and it was not identical to the spectra of the "benzene" eluates from fish. The spectrum of the 90:10 benzene: ethyl ether fraction given in Fig. 22, showed that other material, probably having a carbonyl ($>C=O$) group, was eluted from SCOW. An attempt was made to further purify the benzene fraction from SCOW by rechromatography on alumina. The benzene-eluted material from rechromatography is given in Fig. 23. No further purification seemed to be achieved in this rechromatograph step, since no essential differences were observed on comparison of the spectra (Figs. 22 and 23).

E. Gas Chromatography

The purpose of gas chromatography was to separate and estimate the components in the "cyclohexane" and "benzene-benzene/ ethyl ether" fractions. These fractions were recovered from column chromatography of the SCOW and fish extracts after saponification.

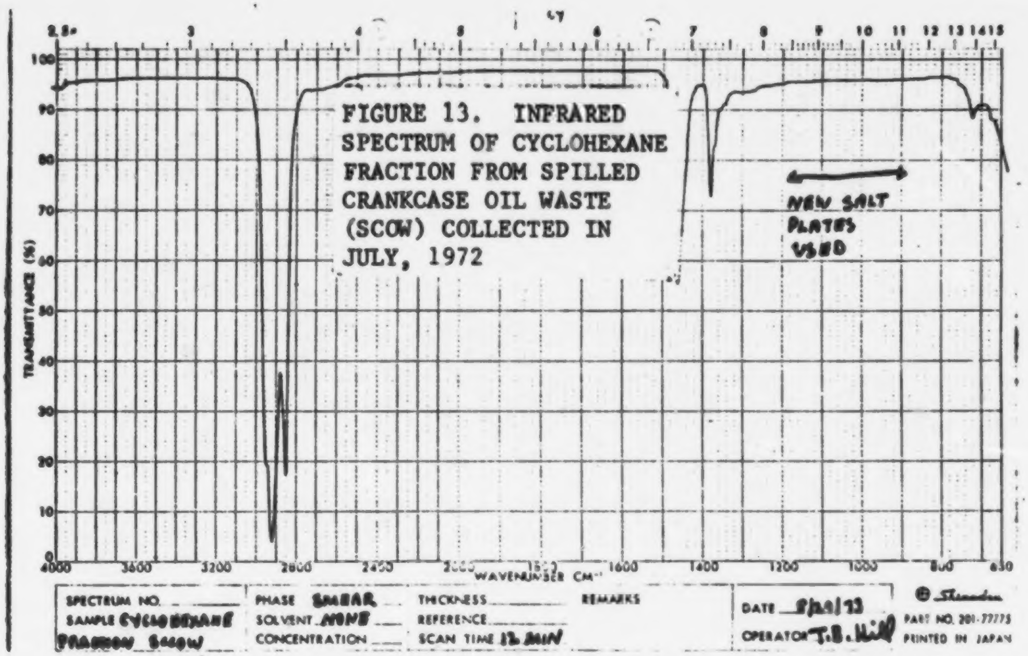

FIGURE 13. INFRARED SPECTRUM OF CYCLOHEXANE FRACTION FROM SPILLED CRANKCASE OIL WASTE (SCOW) COLLECTED IN JULY, 1972

SPECTRUM NO. ____
SAMPLE CYCLOHEXANE FRACTION SCOW
PHASE SMEAR
SOLVENT NONE
CONCENTRATION ____
THICKNESS ____
REFERENCE ____
SCAN TIME 12 MIN
REMARKS
DATE 8/29/73
OPERATOR T.B. Hill

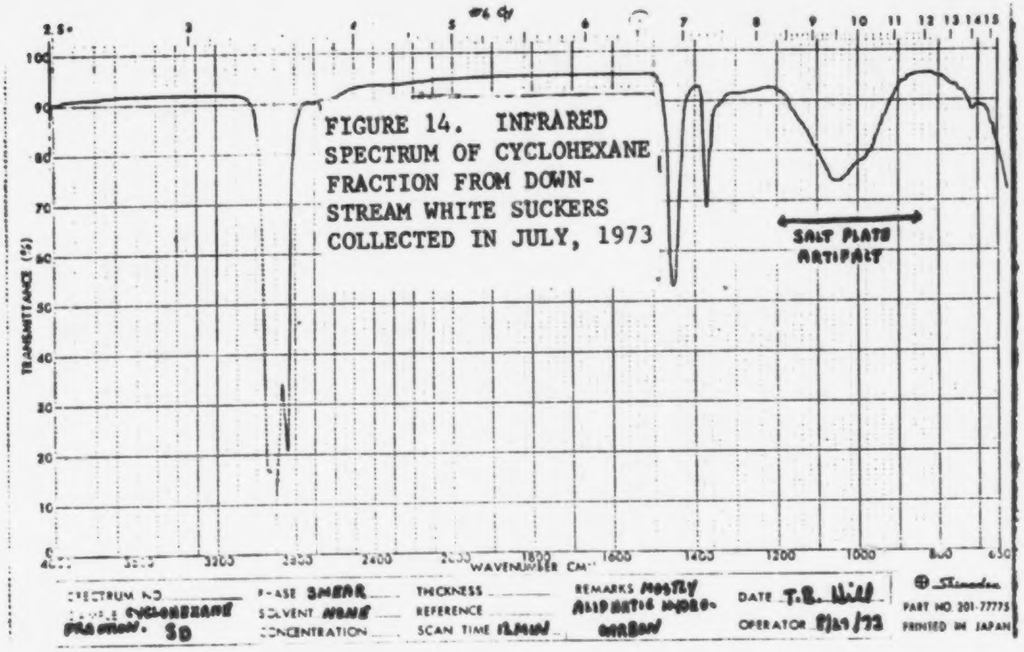

FIGURE 14. INFRARED SPECTRUM OF CYCLOHEXANE FRACTION FROM DOWN-STREAM WHITE SUCKERS COLLECTED IN JULY, 1973

SPECTRUM NO. ____
SAMPLE CYCLOHEXANE FRACTION. SD
PHASE SMEAR
SOLVENT NONE
CONCENTRATION ____
THICKNESS ____
REFERENCE ____
SCAN TIME 12 MIN
REMARKS MOSTLY ALIPHATIC HYDRO-CARBON
DATE T.B. Hill
OPERATOR 8/29/73

The technique has developed in practice to the extent that a present-day working organic chemist cannot function without a gas chromatograph. If the peaks observed in the gas chromatogram of a complex mixture are well resolved, the analyst has an opportunity to:

1) tentatively establish, but not prove, the presence of a given component by adding known compounds to the sample, rerunning the chromatogram, and observing peak height enhancement,

2) establish the definite absence of a given component in the original sample by the same technique as 1) and observe extra peaks in the chromatogram of the sample doped with known compounds (assuming no background) or

3) conclusively identify a compound from the gas chromatograph by trapping the effluent gas from each peak after the component passes the detector, thereby isolating the component to study other physical properties. This latter technique can be applied where a) the sample is not destroyed by the detector, b) relatively large amounts of samples are available, and c) a relatively large column is used.

In the case of complex mixtures, the gas chromatogram may show only poorly resolved peaks against a large "background." If the chromatograms of two samples of multi-component mixtures have identical peaks of similar relative intensity, the samples are presumed to be identical. This "fingerprint" technique has been studied with some success in efforts to identify the source in crude oil spills. That success is due to the fact that different crude oils, while extremely complex in their chemical composition, show significant differences in their gas chromatograms.

The application of fingerprint gas chromatography to identify hydrocarbons in marine life has been applied with some success by Blumer et al. (1970) and by Connell (1971). Connell obtained fingerprints on extracts of the Australian mullet and compared these to substances isolated from river sediments.

Blumer, M., G. Souza, and J. Sass. 1970. "Hydrocarbon Pollution of Edible Shellfish by an Oil Spill," Biol. 5:195.

Connell, D. W. 1971. "Kerosene-like tainting in the Australian Mullet," Marine Pollution Bulletin, 12 (2): 188.

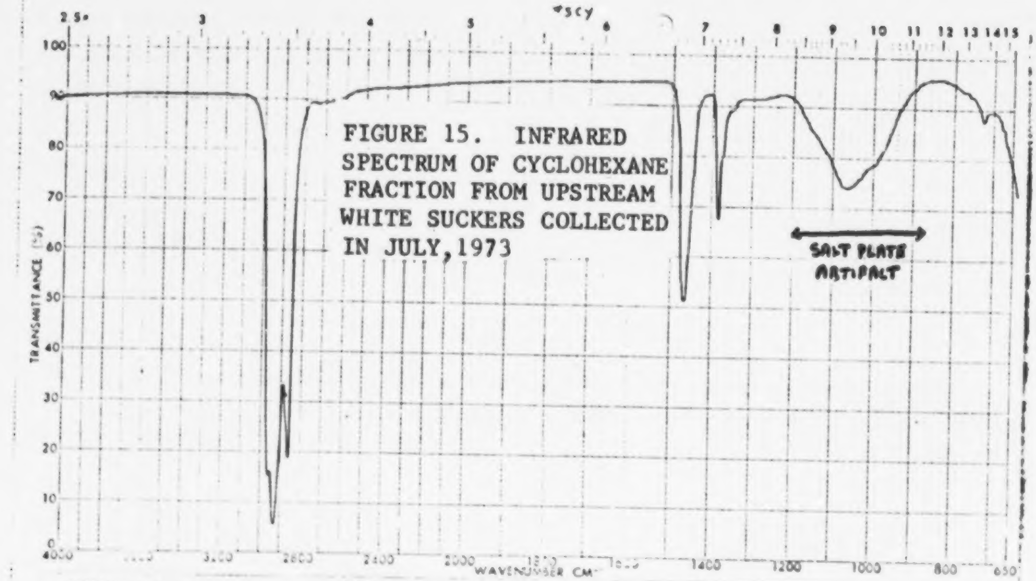

FIGURE 15. INFRARED SPECTRUM OF CYCLOHEXANE FRACTION FROM UPSTREAM WHITE SUCKERS COLLECTED IN JULY, 1973

SPECTRUM NO
SAMPLE CYCLOHEXANE FRACTION S.U.
PHASE SMEAR
SOLVENT NONE
CONCENTRATION
THICKNESS
REFERENCE
SCAN TIME 12 MIN
REMARKS MOSTLY ALIPHATIC HYDRO-CARBON
DATE 9/27/73
OPERATOR T.B. Hill
Shimadzu
PART NO 201-77775
PRINTED IN JAPAN

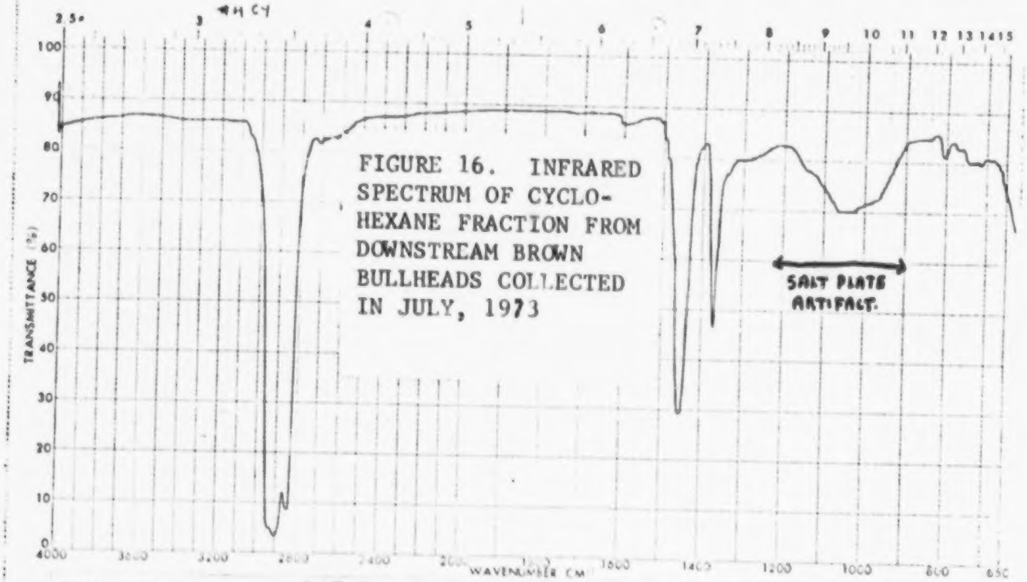

FIGURE 16. INFRARED SPECTRUM OF CYCLOHEXANE FRACTION FROM DOWNSTREAM BROWN BULLHEADS COLLECTED IN JULY, 1973

SPECTRUM NO
SAMPLE CYCLOHEXANE FRACTION. BD
PHASE SMEAR
SOLVENT NONE
CONCENTRATION
THICKNESS —
REFERENCE —
SCAN TIME 12 MIN
REMARKS
DATE 8/24/73
OPERATOR T.B. Hill
Shimadzu
PART NO 201-77775
PRINTED IN JAPAN

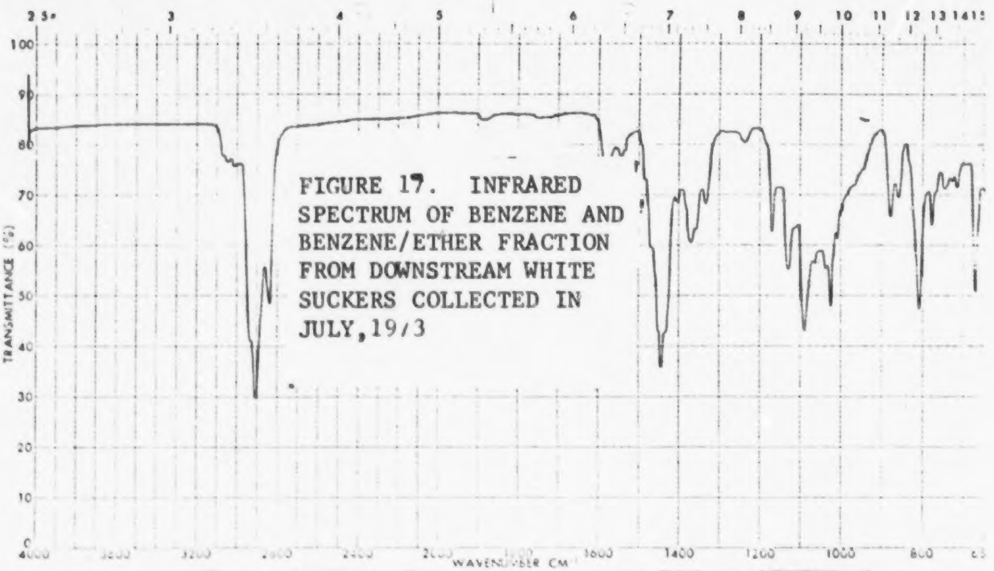

FIGURE 17. INFRARED SPECTRUM OF BENZENE AND BENZENE/ETHER FRACTION FROM DOWNSTREAM WHITE SUCKERS COLLECTED IN JULY, 1973

SPECTRUM NO ______ PHASE **SMEAR** THICKNESS ______ REMARKS

SAMPLE **BENZENE + BENZENE/ETHER FRACTION S.D.** SOLVENT **NONE** REFERENCE

CONCENTRATION SCAN TIME **12 MIN**

DATE **8/28/73**

OPERATOR **T.B. Hill**

Shimadzu PART NO 201-77775 PRINTED IN JAPAN

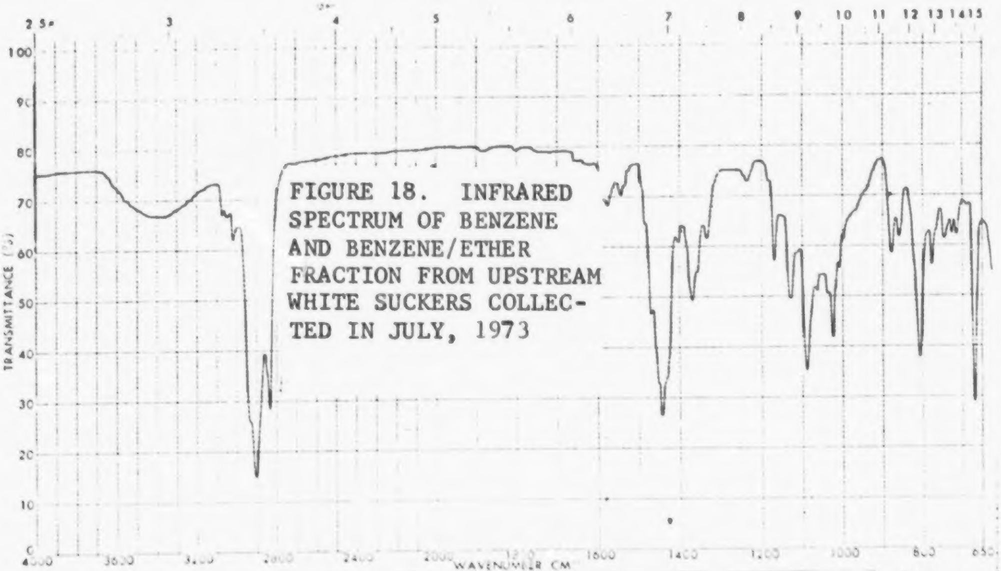

FIGURE 18. INFRARED SPECTRUM OF BENZENE AND BENZENE/ETHER FRACTION FROM UPSTREAM WHITE SUCKERS COLLECTED IN JULY, 1973

SPECTRUM NO ______ PHASE **SMEAR** THICKNESS ______ REMARKS

SAMPLE **BENZENE + BENZENE/ETHER FRACTION S.U.** SOLVENT **NONE** REFERENCE

CONCENTRATION SCAN TIME **12 MIN**

DATE **8/27/73**

OPERATOR **T.B. Hill**

Shimadzu PART NO 201-77775 PRINTED IN JAPAN

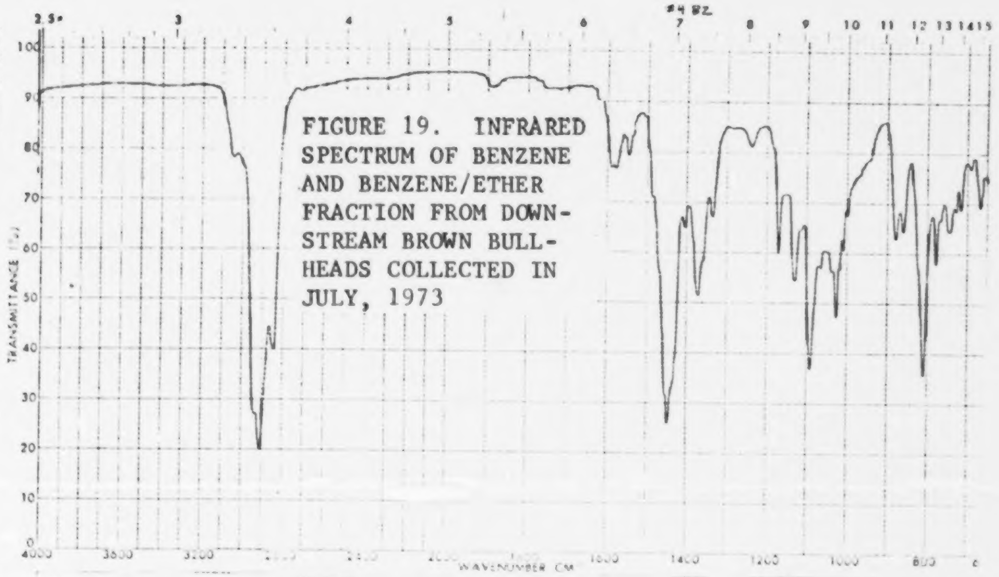

FIGURE 19. INFRARED SPECTRUM OF BENZENE AND BENZENE/ETHER FRACTION FROM DOWNSTREAM BROWN BULLHEADS COLLECTED IN JULY, 1973

SPECTRUM NO
SAMPLE BENZENE + BENZENE/ETHER FRACTION B.D.
PHASE SMEAR
SOLVENT NONE
CONCENTRATION
THICKNESS
REFERENCE
SCAN TIME 12 MIN
REMARKS
DATE 9/27/73
OPERATOR T.B. Hill
Shimadzu
PART NO 201 777
PRINTED IN JAP.

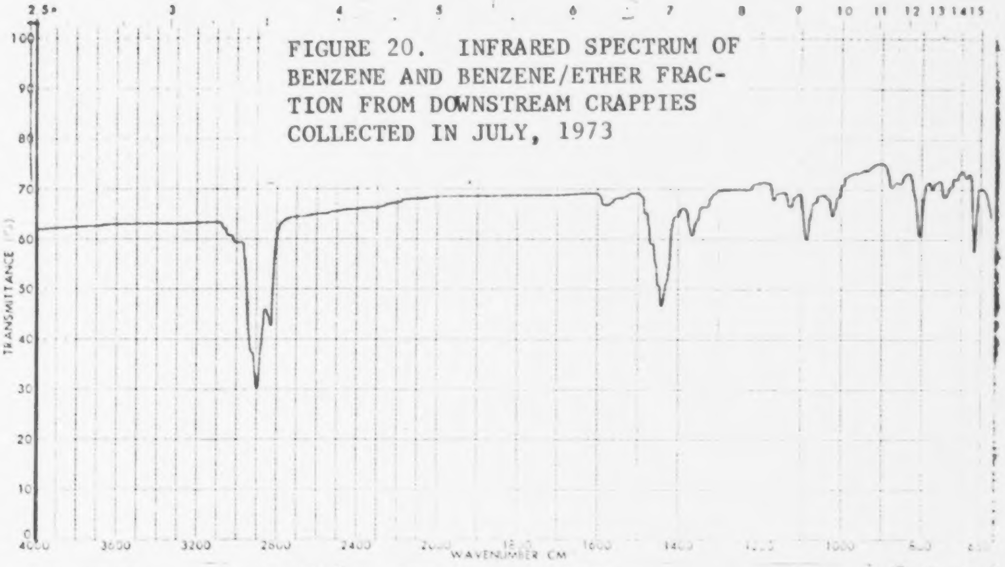

FIGURE 20. INFRARED SPECTRUM OF BENZENE AND BENZENE/ETHER FRACTION FROM DOWNSTREAM CRAPPIES COLLECTED IN JULY, 1973

SPECTRUM NO
SAMPLE BENZENE + BENZENE/ETHER CD
PHASE SMEAR
SOLVENT NONE
CONCENTRATION
THICKNESS –
REFERENCE –
SCAN TIME 6 MIN
REMARKS
DATE 8/30/73
OPERATOR T.B. Hill
Shimadzu
PRINTED IN JAPAN

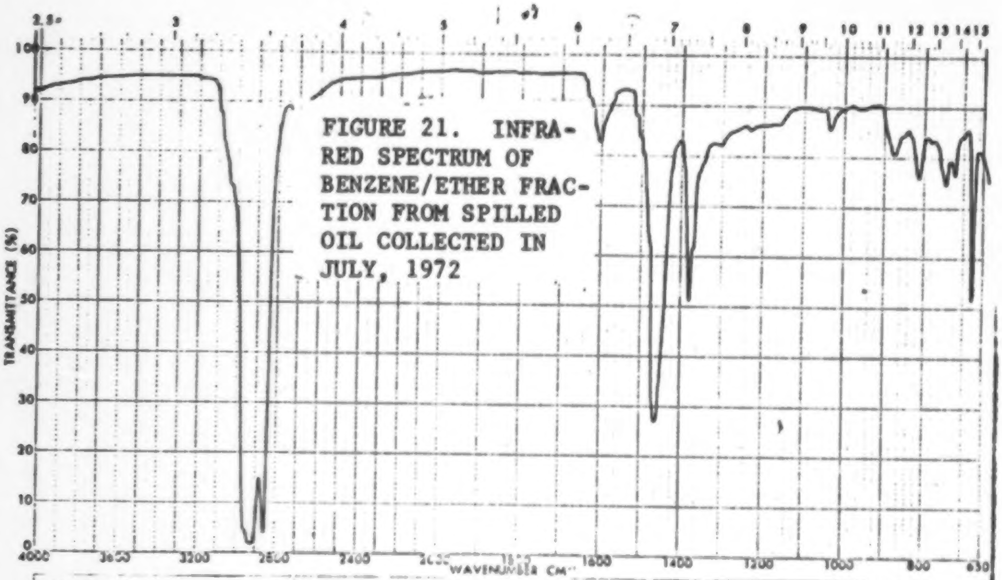

FIGURE 21. INFRARED SPECTRUM OF BENZENE/ETHER FRACTION FROM SPILLED OIL COLLECTED IN JULY, 1972

SPECTRUM NO. ____
SAMPLE BENZENE FRACTION SCCOW
PHASE SMEAR
SOLVENT NONE
CONCENTRATION ____
THICKNESS ____
REFERENCE ____
SCAN TIME 12 MIN.
REMARKS
DATE 9/29/73
OPERATOR T.B. Hill
Shimadzu
PART NO. 201-77775
PRINTED IN JAPAN

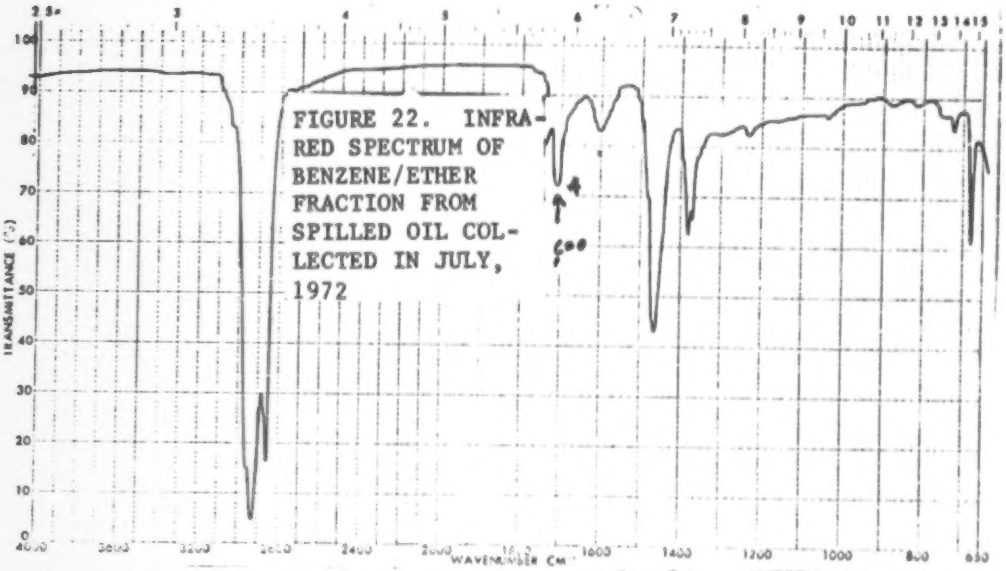

FIGURE 22. INFRARED SPECTRUM OF BENZENE/ETHER FRACTION FROM SPILLED OIL COLLECTED IN JULY, 1972

SPECTRUM NO ____
SAMPLE BENZENE/ETHER FRACTION (SCCOW)
PHASE SMEAR
SOLVENT NONE
CONCENTRATION
THICKNESS
REFERENCE
SCAN TIME 12 MIN
REMARKS * 5.85μ INDICATES CARBONYL GROUP
DATE 9/19/73
OPERATOR T.B. Hill
Shimadzu
PART NO 201 77775
PRINTED IN JAPAN

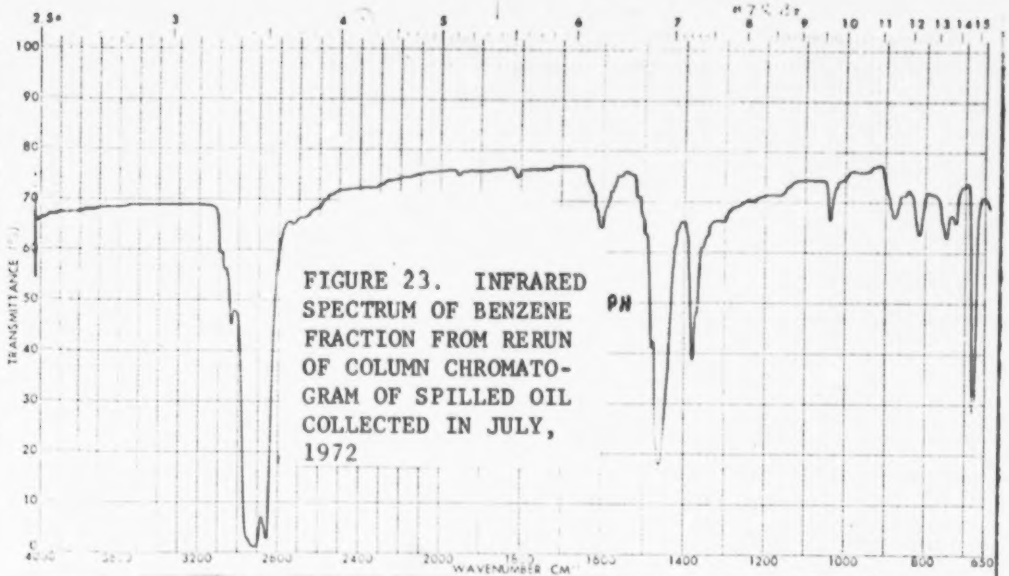

FIGURE 23. INFRARED SPECTRUM OF BENZENE FRACTION FROM RERUN OF COLUMN CHROMATOGRAM OF SPILLED OIL COLLECTED IN JULY, 1972

SPECTRUM NO
SAMPLE BENZENE FRACTION: RERUN SCLOW
PHASE SMEAR
SOLVENT NONE
CONCENTRATION
THICKNESS
REFERENCE
SCAN TIME 12 MIN
REMARKS
DATE 8/29/73
OPERATOR T.B. Hill

Shimadzu
PART NO 201-77775
PRINTED IN JAPAN

The spilled crankcase oil waste was an extremely complex mixture as indicated by the large unresolved backgrounds in the chromatograms of the waste oil (Figs. 24 and 25).

In this study two sets of gas chromatograms were determined on refined extracts from fish and waste crankcase oil.

1) the cyclohexane fraction from column chromatography on alumina using a 6' by 1/8" OV-17 column programmed from 50-293°C at 8°C per minute.

2) the benzene (actually benzene + benzene/ethyl ether) fraction from column chromatography on alumina using a 7' by 1/8" SE-52 column programmed from 50 to 293°C at 8°C per minute.

Both of these columns were methyl phenyl silicone gum rubber columns. The OV-17 column was used by the Virginia Institute of Marine Science (Gloucester Point, Virginia) for analysis of crude oils, while the SE-52 column was used specifically for the analysis of polycyclic aromatic hydrocarbons by Chatot et al. (1969).

F. Cyclohexane Fractions

Gas chromatograms were obtained on cyclohexane fractions from column chromatography of spilled crankcase oil waste (Fig. 24), upstream white suckers (Fig. 26), downstream white suckers (Fig. 27), downstream brown bullheads (Fig. 28),and downstream crappies (Fig. 29). These samples were chromatographed by a prebaking process in which the sample was placed in a small aluminum foil cup and baked for five minutes inside the injection port of the instrument before the temperature program was started.

While the infrared evidence (page 55) clearly illustrated the presence of aliphatic hydrocarbons in all cyclohexane fractions of SCOW and fish, the gas chromatograms (Figs. 24, 26-29) indeed illustrated their expected complexity. All samples showed a broad, undefined background ranging from approximately 140°C to 270°C. However, no consistent fingerprint pattern was evident on comparing the relatively small peaks superimposed on the prominant background.

Chatot, G., Jequier, W., Jay, M., and Fontanges, R. 1969. "Study of Atmospheric Polycyclic Hydrocarbons: Problems Connected with Coupling of Thin Layer Chromatography with Gas Phase Chromatography," Journal Chromatography 45:415.

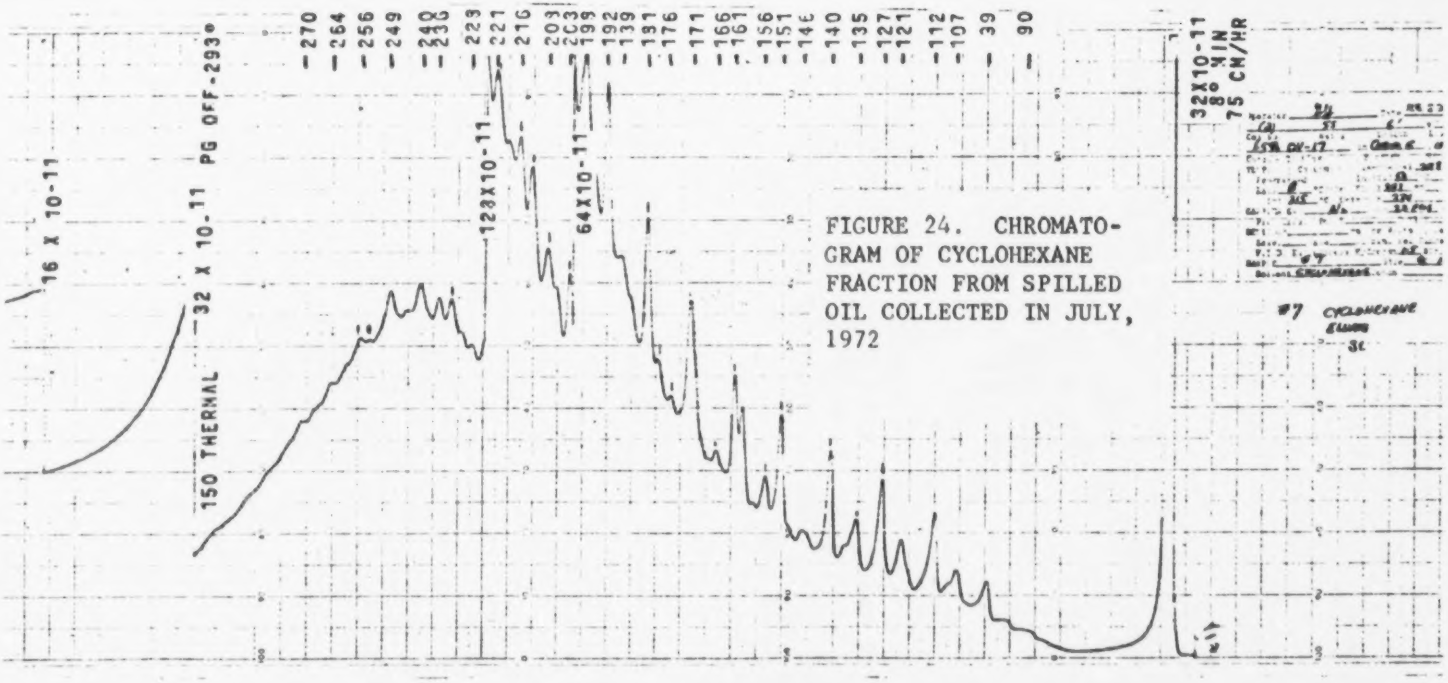

FIGURE 24. CHROMATOGRAM OF CYCLOHEXANE FRACTION FROM SPILLED OIL COLLECTED IN JULY, 1972

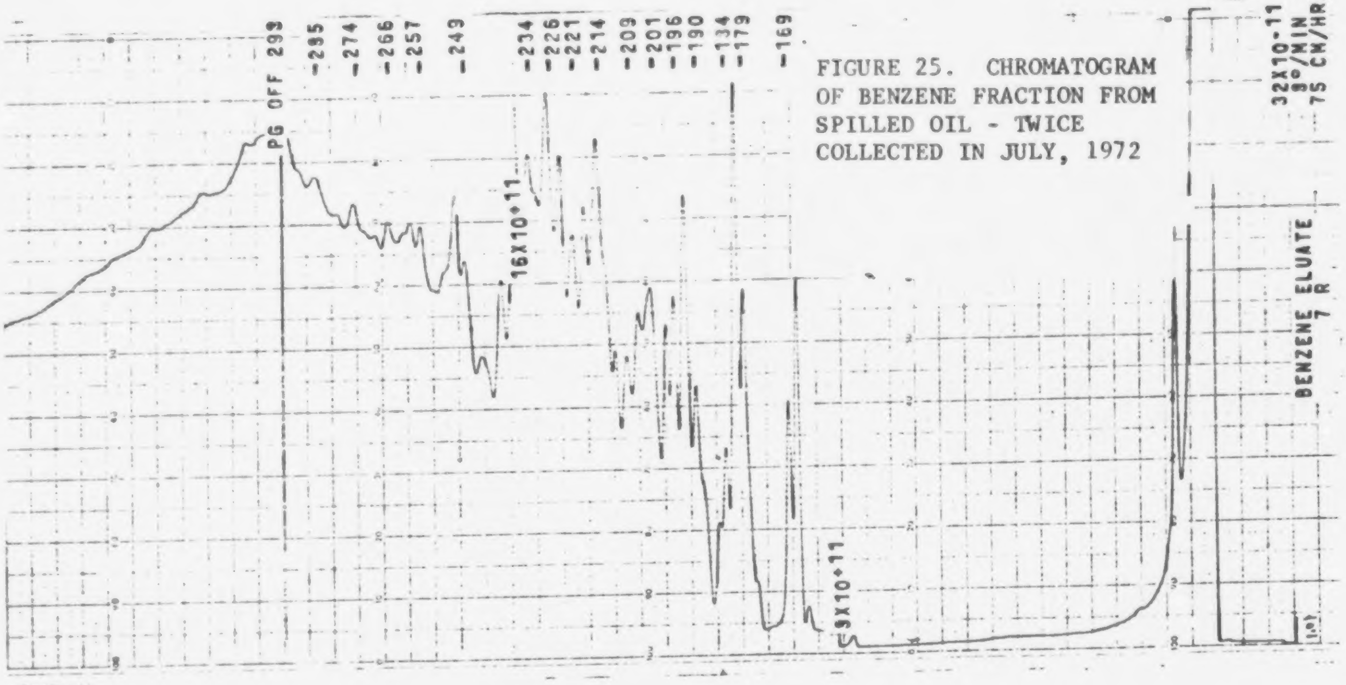

FIGURE 25. CHROMATOGRAM OF BENZENE FRACTION FROM SPILLED OIL - TWICE COLLECTED IN JULY, 1972

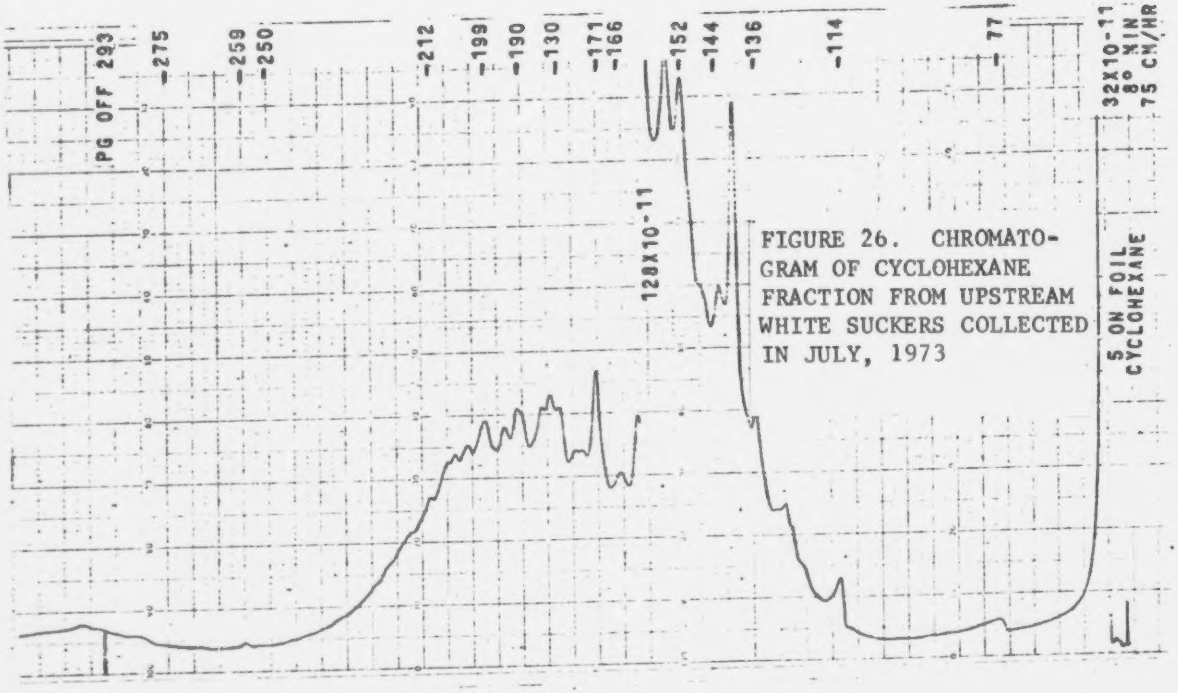

FIGURE 26. CHROMATOGRAM OF CYCLOHEXANE FRACTION FROM UPSTREAM WHITE SUCKERS COLLECTED IN JULY, 1973

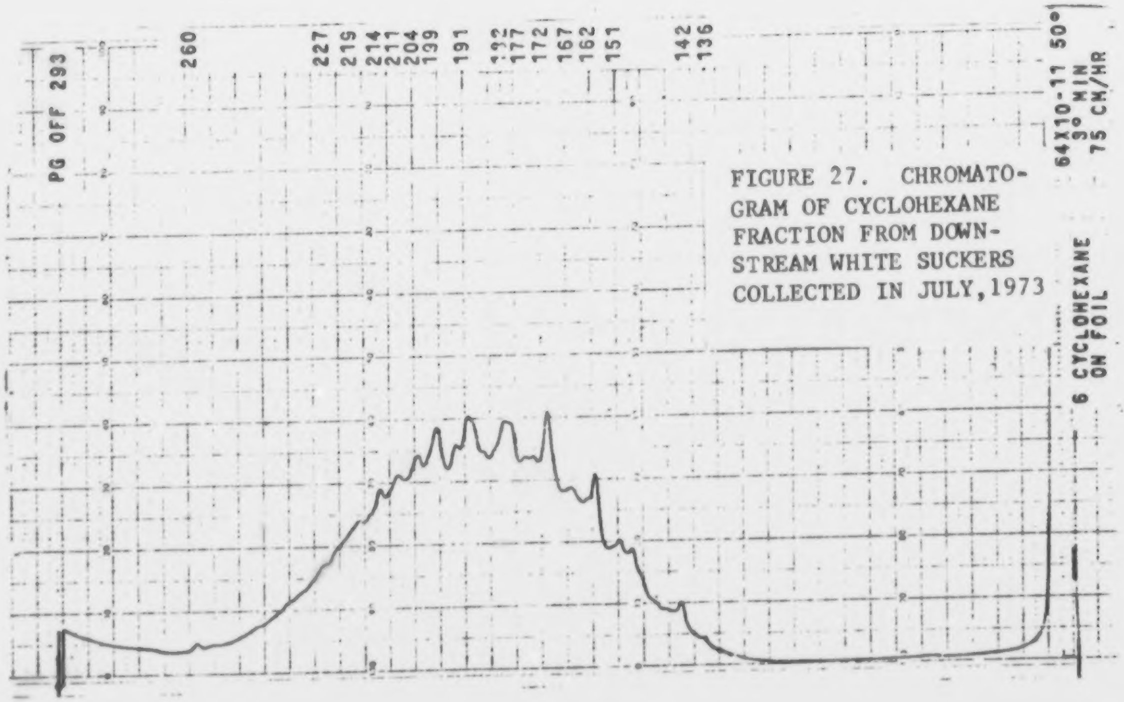

FIGURE 27. CHROMATOGRAM OF CYCLOHEXANE FRACTION FROM DOWNSTREAM WHITE SUCKERS COLLECTED IN JULY, 1973

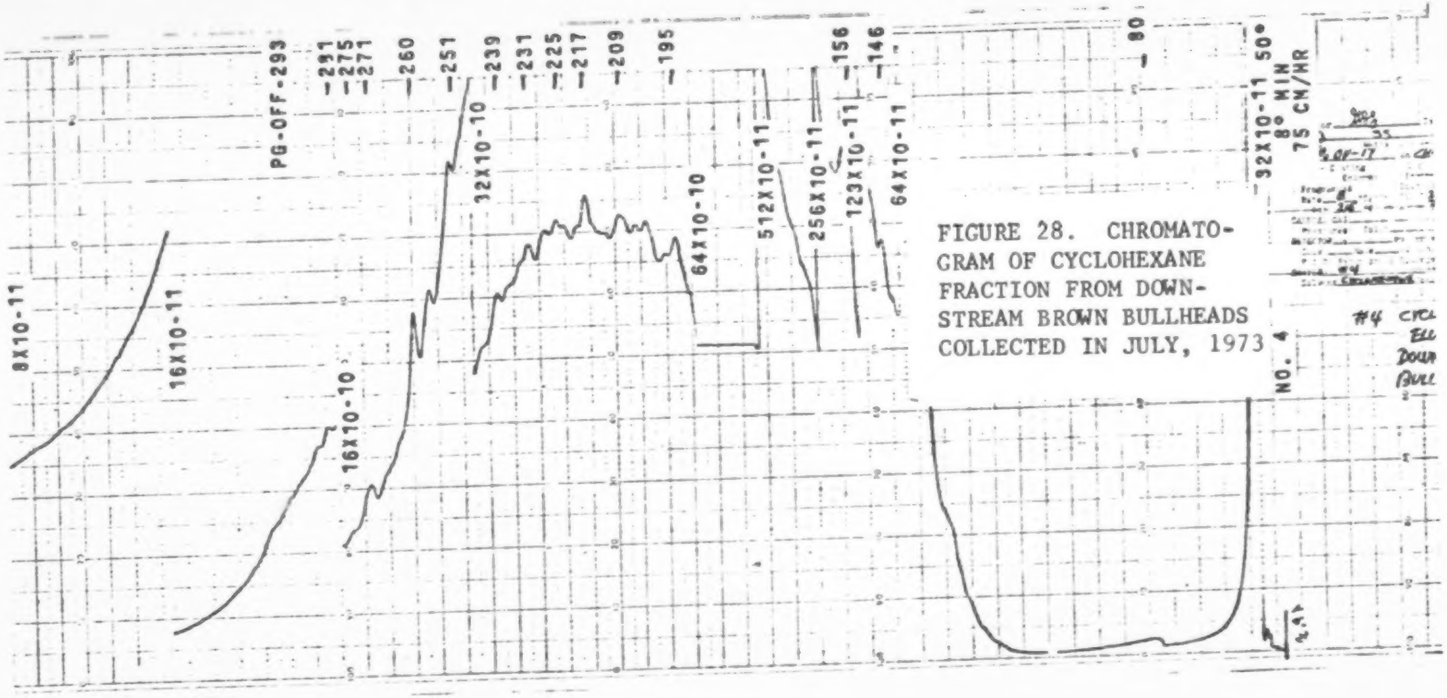

FIGURE 28. CHROMATOGRAM OF CYCLOHEXANE FRACTION FROM DOWNSTREAM BROWN BULLHEADS COLLECTED IN JULY, 1973

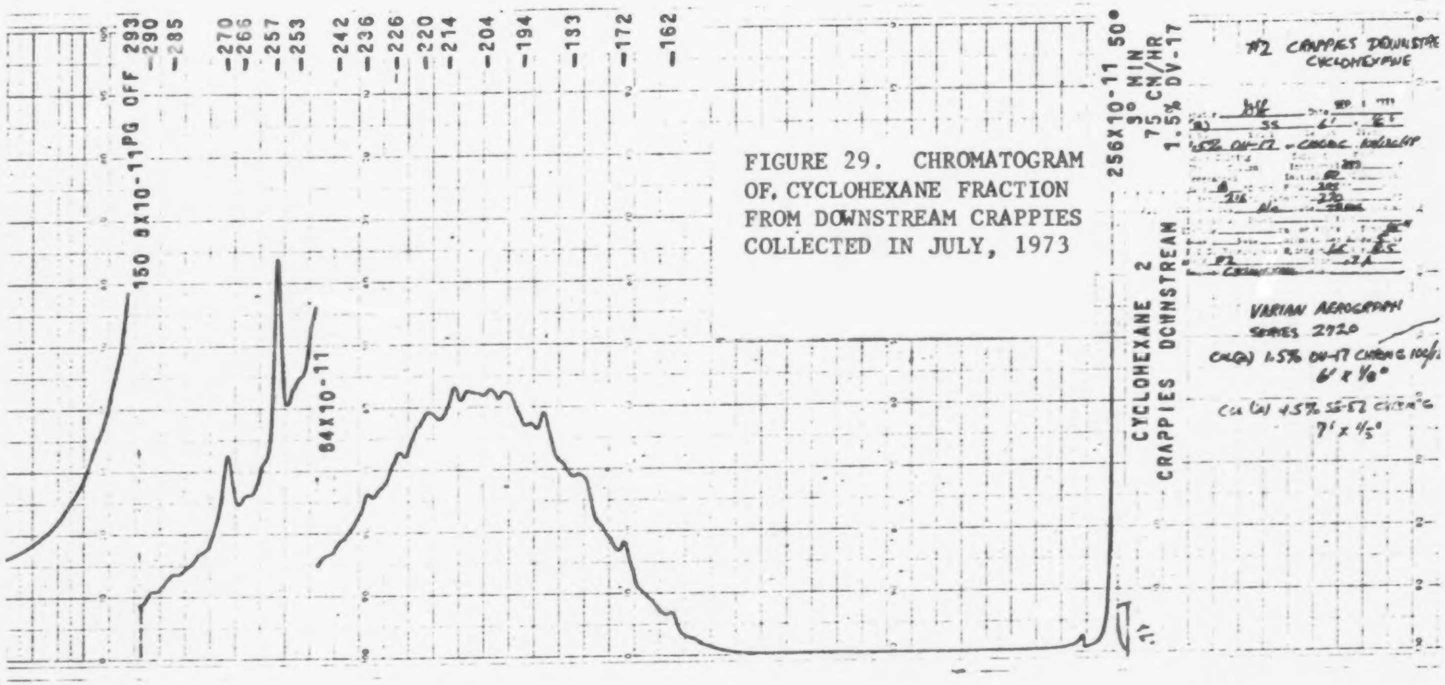

FIGURE 29. CHROMATOGRAM OF CYCLOHEXANE FRACTION FROM DOWNSTREAM CRAPPIES COLLECTED IN JULY, 1973

G. Benzene-Benzene/Ether Fractions

In contrast to the cyclohexane fractions, the gas chromatograms from the "benzene" fraction of fish showed very well resolved peaks with much less background. A typical example was seen in the chromatogram of the upstream suckers (Fig. 30). This chromatogram showed at least twenty-one well resolved peaks, thus offering an excellent chance for peak matching studies with authentic samples of polycyclic aromatic hydrocarbons.

A peak to peak analysis of the chromatograms from the benzene fraction of fish will not be detailed here. The chromatograms of the downstream suckers (Fig. 31), downstream brown bullheads (Fig. 32), and downstream crappies (Fig. 33) samples all showed remarkable similarity with many matching peaks. Admittedly, many of these peaks varied in intensity, but their retention times were quite reproducible.

While the gas chromatogram of the benzene fraction from rechromatographed SCOW (Fig. 25) showed many well-resolved peaks, it also contained a very large undefined background. As discussed above, this was due to the complexity of the spilled material. The pattern differed from those of fish. Many peaks matched, but there were many others of questionable identity.

H. Peak Matching Studies by Chromatography

Peak matching studies of the benzene eluate from upstream white suckers (Fig. 30) were conducted. This chromatogram was compared with chromatograms of the same sample spiked with individual polycyclic aromatic hydrocarbons. A list of these aromatics, their structures and sources are given in Fig. 34. These hydrocarbons, except for phenanthrene, were found in oysters by Cahnmann and Kuratsune (1957).

The chromatogram of the mixture of these polycyclic aromatics is given in Fig. 35, which was obtained from a standard solution containing 0.116 mg/ml of each aromatic. The location of

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Cahnmann, H. and M. Kuratsune. 1957. "Determination of Polycyclic Aromatic Hydrocarbons in Oysters Collected in Polluted Water," Anal. Chem. 29:1312.

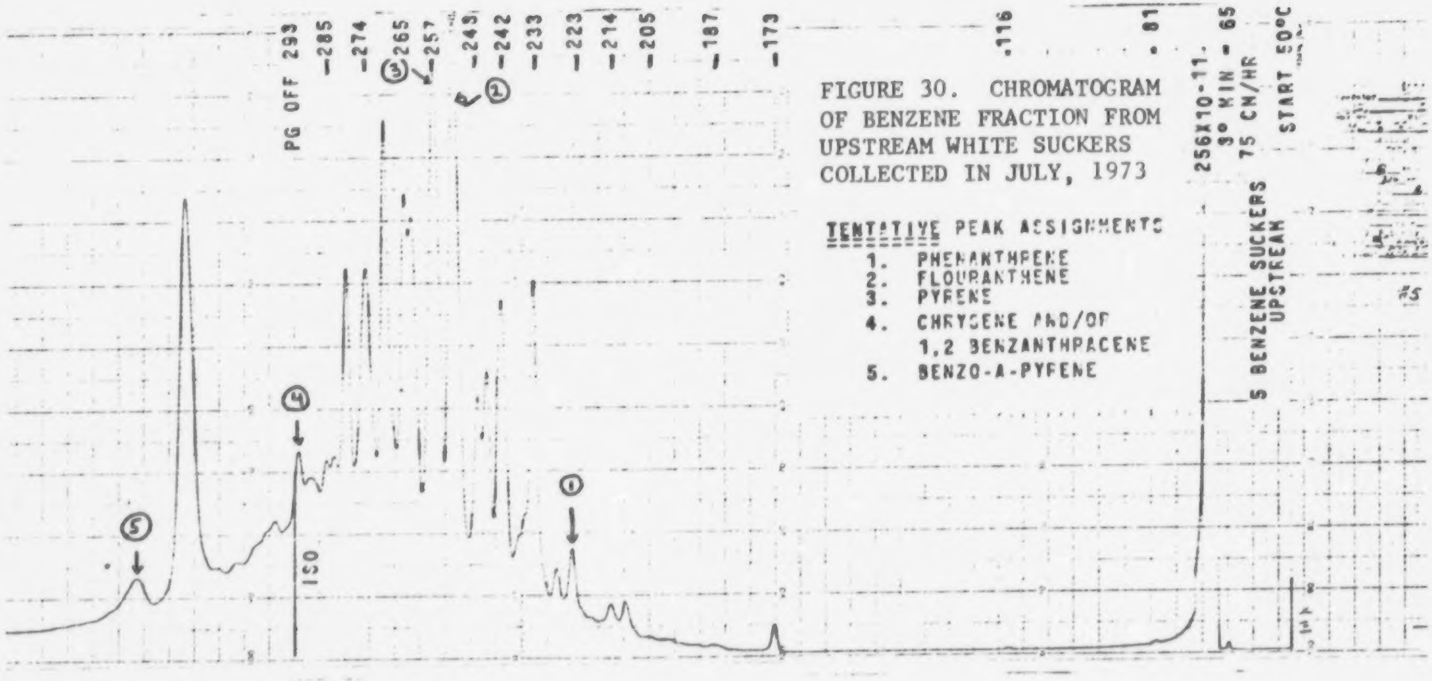


FIGURE 30. CHROMATOGRAM OF BENZENE FRACTION FROM UPSTREAM WHITE SUCKERS COLLECTED IN JULY, 1973

TENTATIVE PEAK ASSIGNMENTS

1. PHENANTHRENE
2. FLOURANTHENE
3. PYRENE
4. CHRYSENE AND/OR
   1,2 BENZANTHRACENE
5. BENZO-A-PYRENE

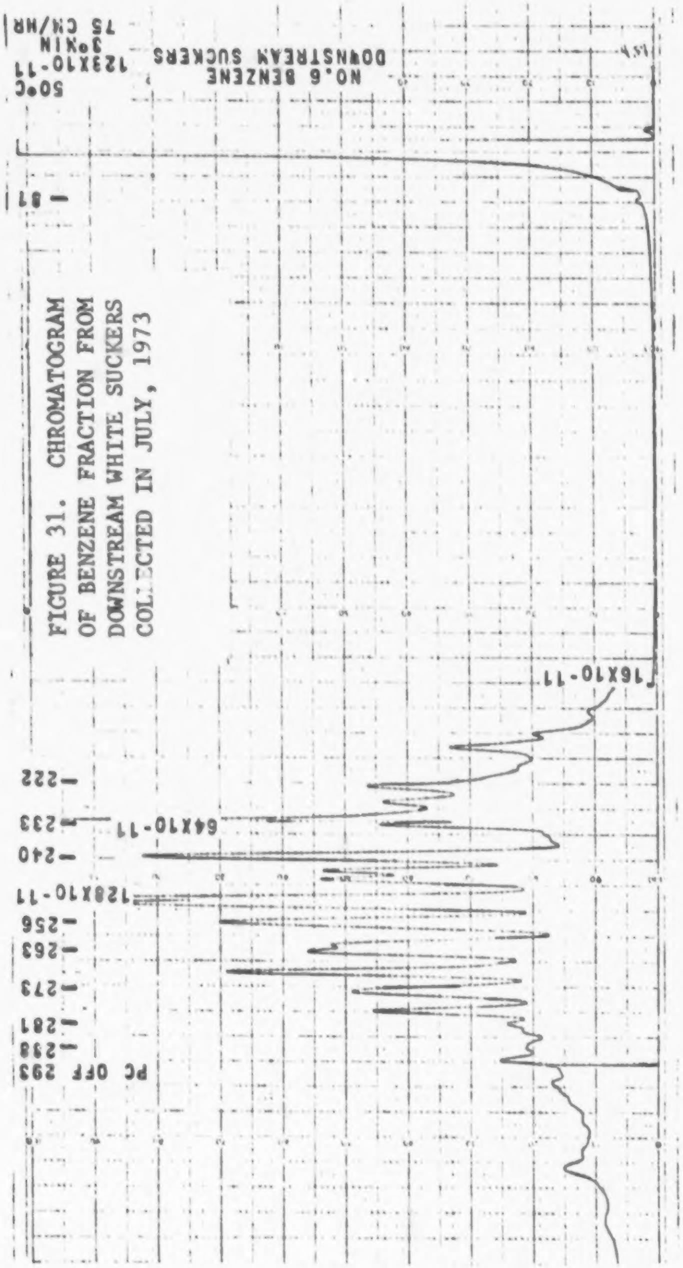


FIGURE 31. CHROMATOGRAM OF BENZENE FRACTION FROM DOWNSTREAM WHITE SUCKERS COLLECTED IN JULY, 1973

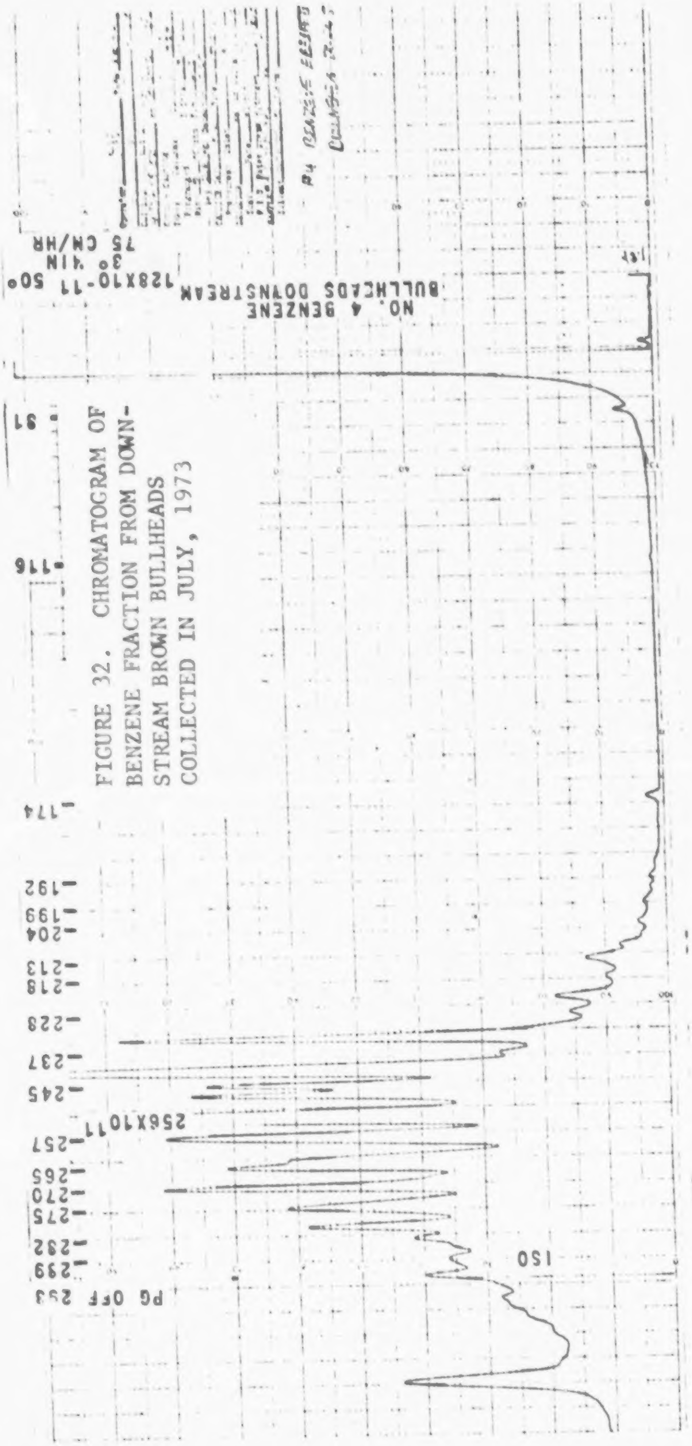


FIGURE 32. CHROMATOGRAM OF BENZENE FRACTION FROM DOWNSTREAM BROWN BULLHEADS COLLECTED IN JULY, 1973

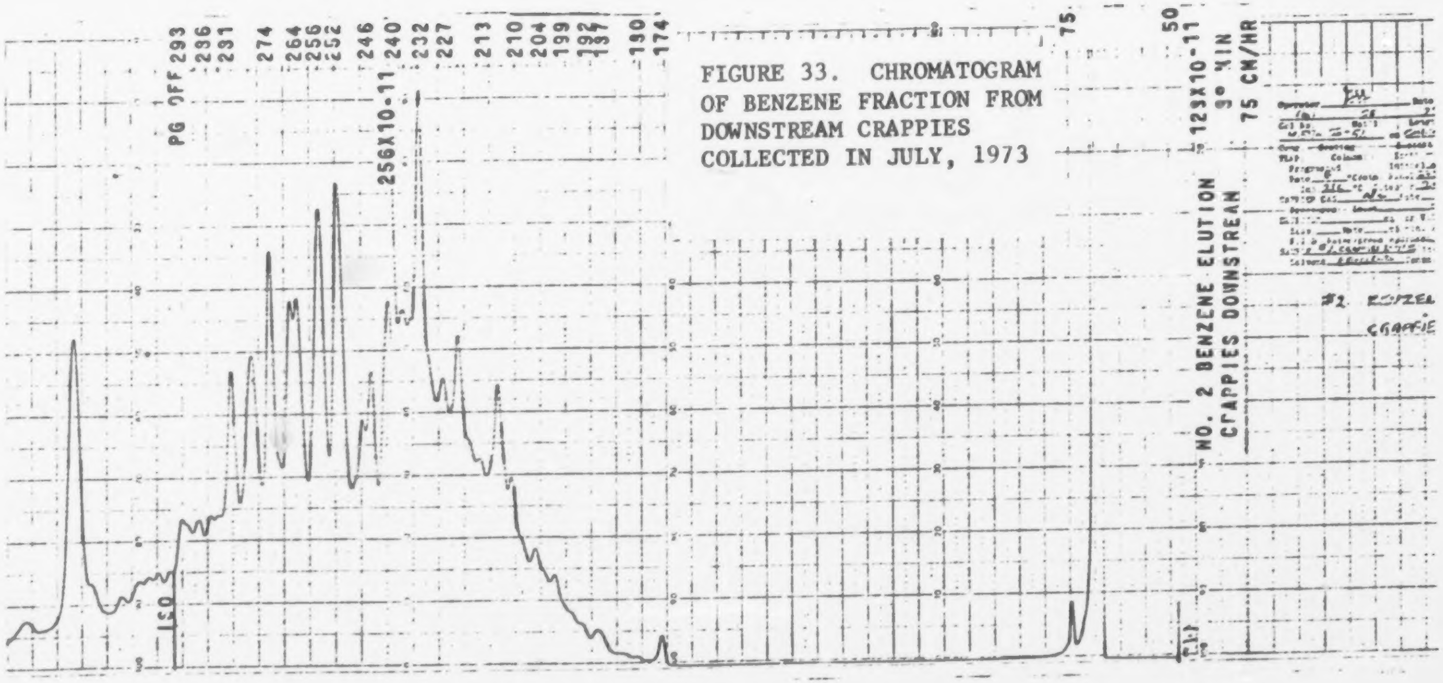
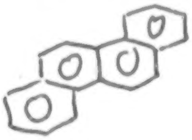
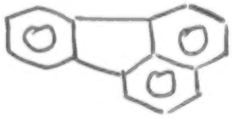
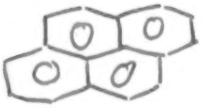
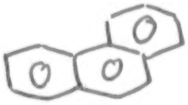
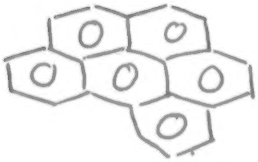
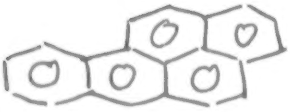
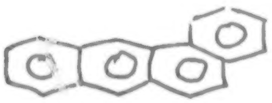


FIGURE 33. CHROMATOGRAM OF BENZENE FRACTION FROM DOWNSTREAM CRAPPIES COLLECTED IN JULY, 1973

Figure 34. Standard polycyclic aromatic hydrocarbons

Name	Chemical Structure	Supplier
Chrysene		Aldrich Chemical Co., 95%
Flouranthene		Aldrich Chemical Co., 99.9+%
Pyrene		Aldricn Chemical Co., zone refined 99.9+%
Phenanthrene		Purified sample prepared by author
Benzo (g,h,i) perylene		Aldrich Chemical Co.
Benzo (a) pyrene		Aldrich Chemical Co.
1,2-Benzanthracene		K & K Laboratories, Inc.

these aromatics as specified on the chromatogram in Fig. 35 was accomplished in a separate study by spiking the mixture with individual standards.

It is to be seen from Fig. 35 that chrysene and 1, 2-benzanthracene were not resolved on an SE-52 column. Furthermore, the heavy polycyclics (benzo-a-pyrene) and benzo (g, h, i) perylene did not emerge from the column until after the temperature program to 293°C was completed.

Tentative assignments of these polycyclic aromatics are given on Fig. 30 for the upstream white suckers, and the gas chromatograms, listed below, supporting these tentative assignments are given in Figs. 36-41.

Known hydrocarbon compounds (Fig. 34) were added to samples of upstream white suckers to tentatively establish the presence of these hydrocarbons in the fish residues by peak enhancement.

Fig. 35	Polycyclic aromatic hydrocarbons each 0.116 mg/ml in benzene
Fig. 36	Upstream white suckers + benzo (a) pyrene
Fig. 37	Upstream white suckers + 1, 2-benzanthracene
Fig. 38	Upstream white suckers + chrysene
Fig. 39	Upstream white suckers + fluoranthene
Fig. 40	Upstream white suckers + pyrene
Fig. 41	Upstream white suckers + phenanthrene

Possibly a benzo (g, h, i) perylene peak was observed in Fig. 47 at 17.5 cm from the isothermal hold period.

I. Kinds and Levels of Hydrocarbons in Fish

The data given to ascertain the kinds and levels of petroleum hydrocarbons in Schuylkill River fish must be treated with caution. The weights of hydrocarbons obtained from column chromatography, given in Table 8, can only be judged in the context of considerable variation in the results of the analytical process, particularly in the saponification step.

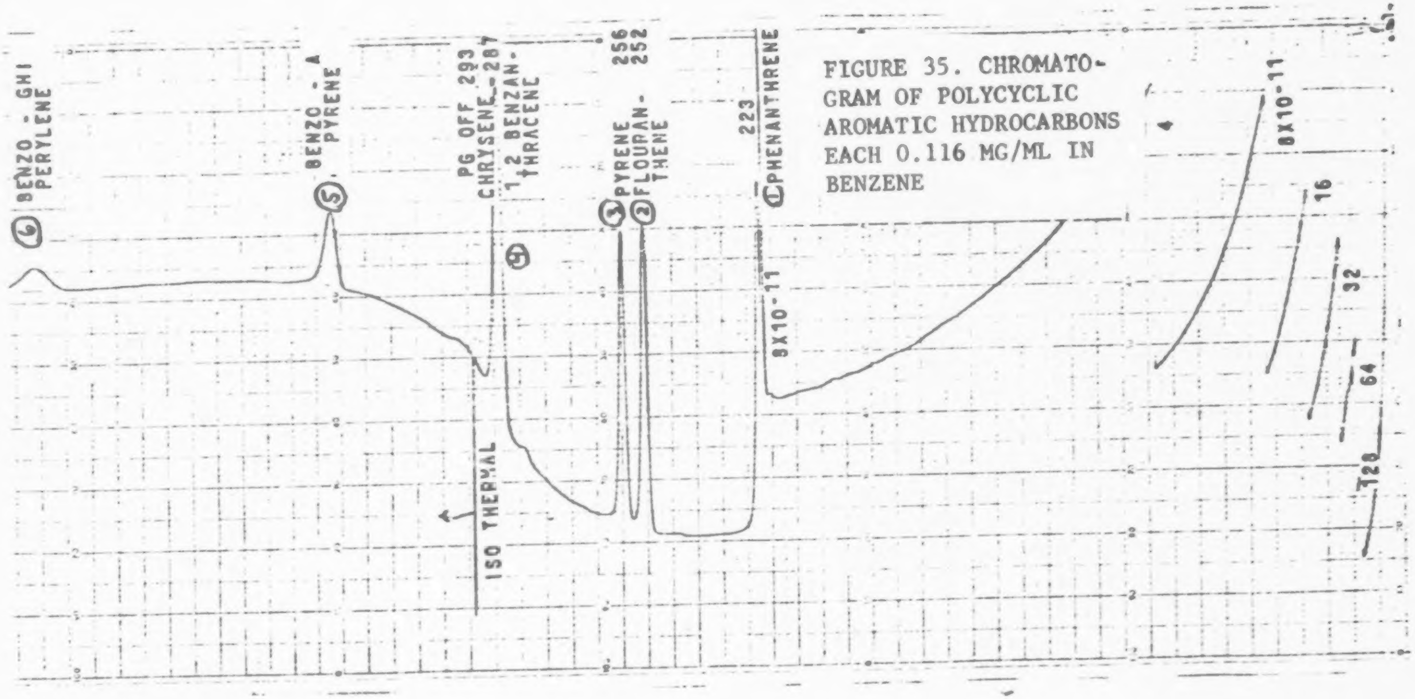


FIGURE 35. CHROMATOGRAM OF POLYCYCLIC AROMATIC HYDROCARBONS EACH 0.116 MG/ML IN BENZENE

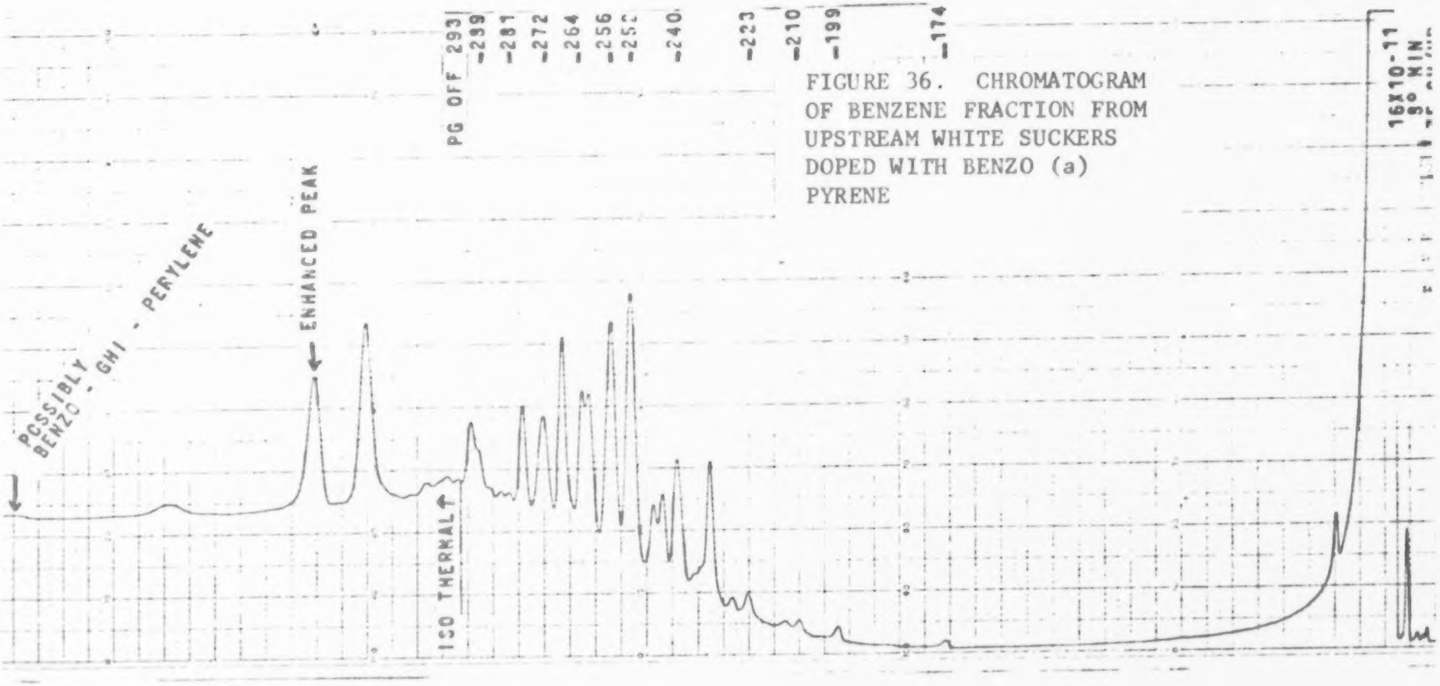


FIGURE 36. CHROMATOGRAM OF BENZENE FRACTION FROM UPSTREAM WHITE SUCKERS DOPED WITH BENZO (a) PYRENE

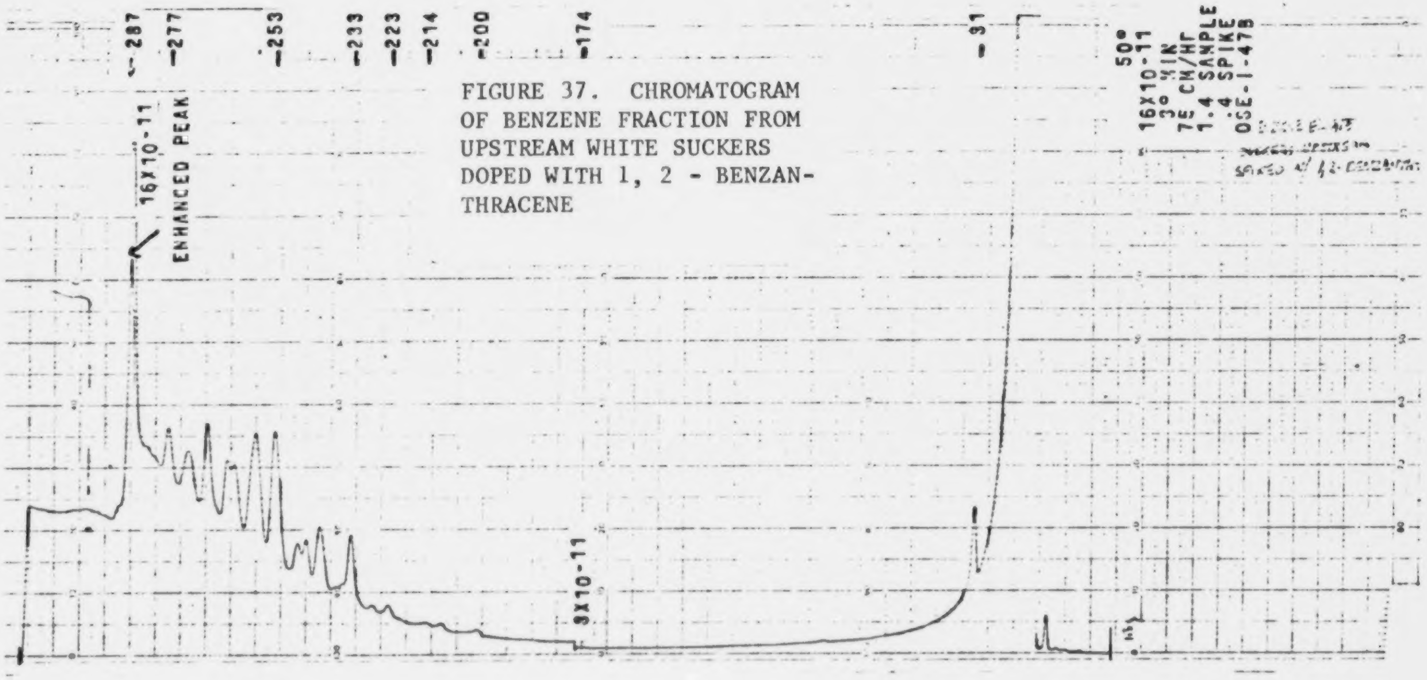


FIGURE 37. CHROMATOGRAM OF BENZENE FRACTION FROM UPSTREAM WHITE SUCKERS DOPED WITH 1, 2 - BENZANTHRACENE

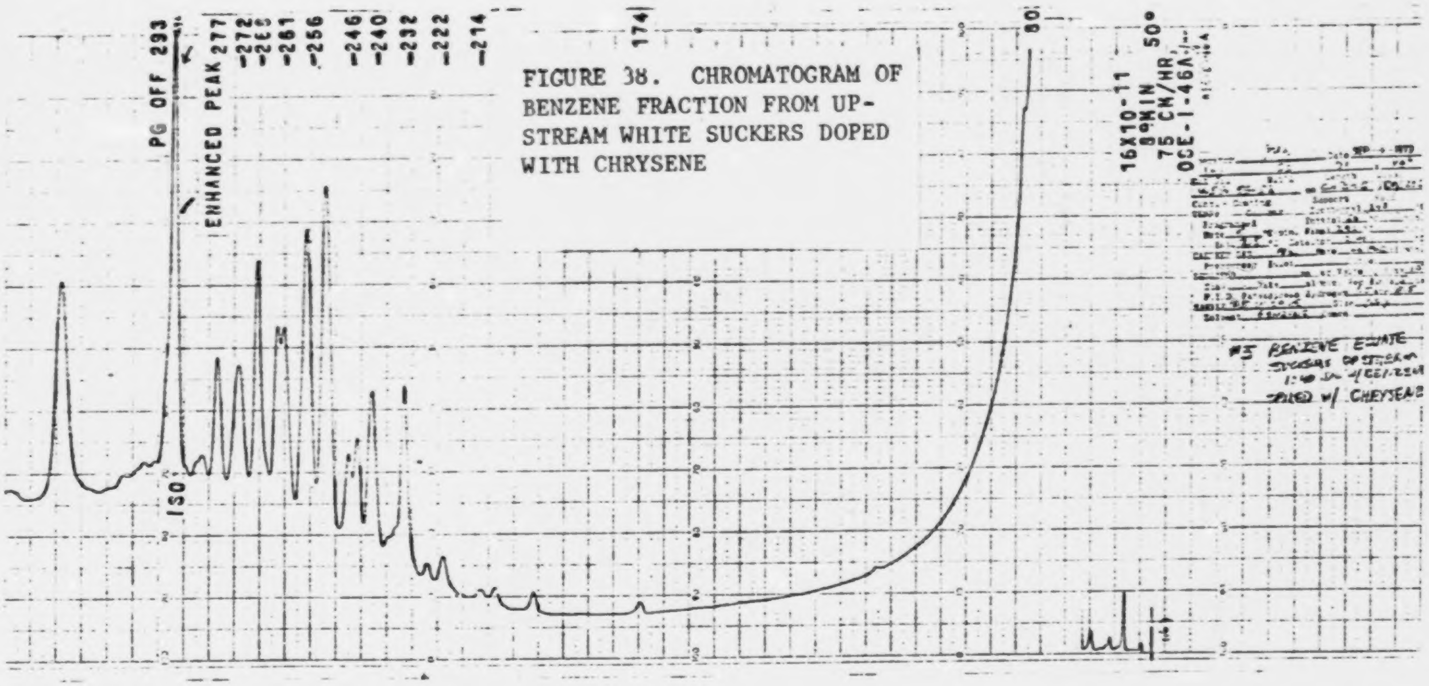


FIGURE 38. CHROMATOGRAM OF BENZENE FRACTION FROM UP-STREAM WHITE SUCKERS DOPED WITH CHRYSENE

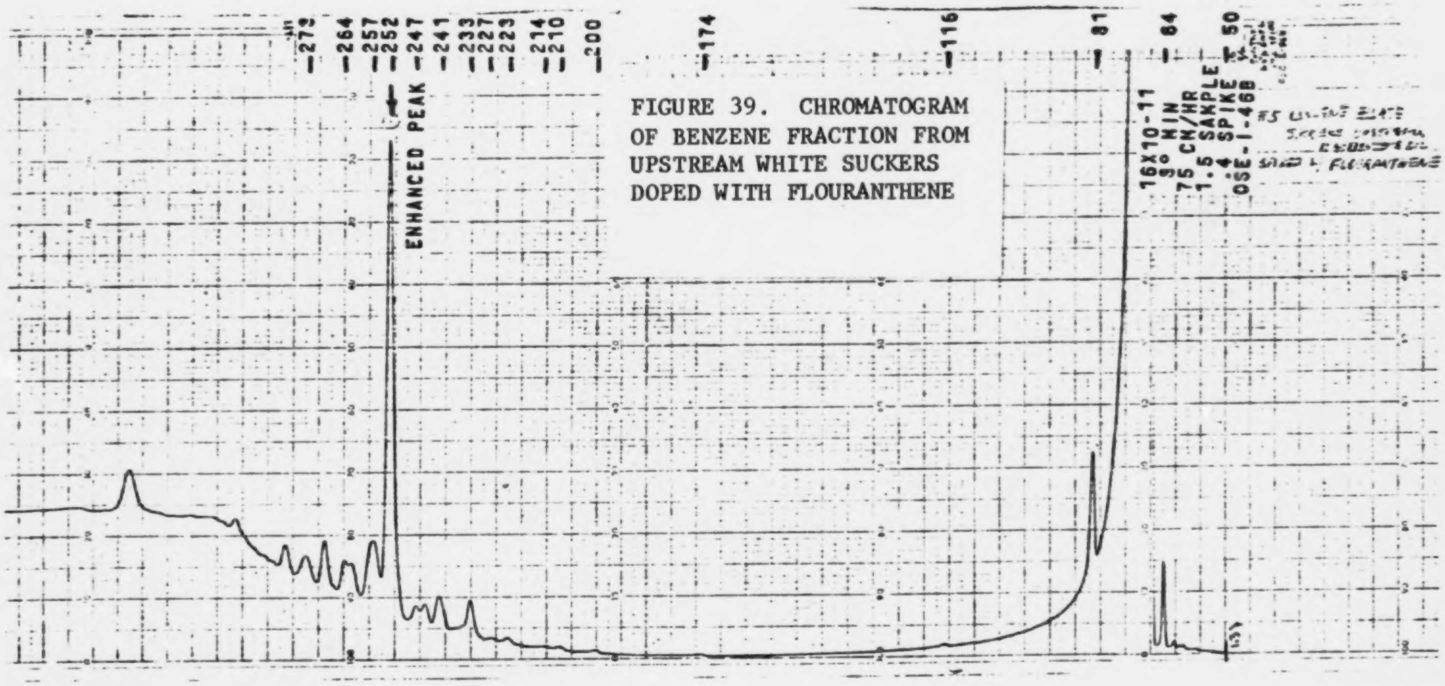


FIGURE 39. CHROMATOGRAM OF BENZENE FRACTION FROM UPSTREAM WHITE SUCKERS DOPED WITH FLOURANTHENE

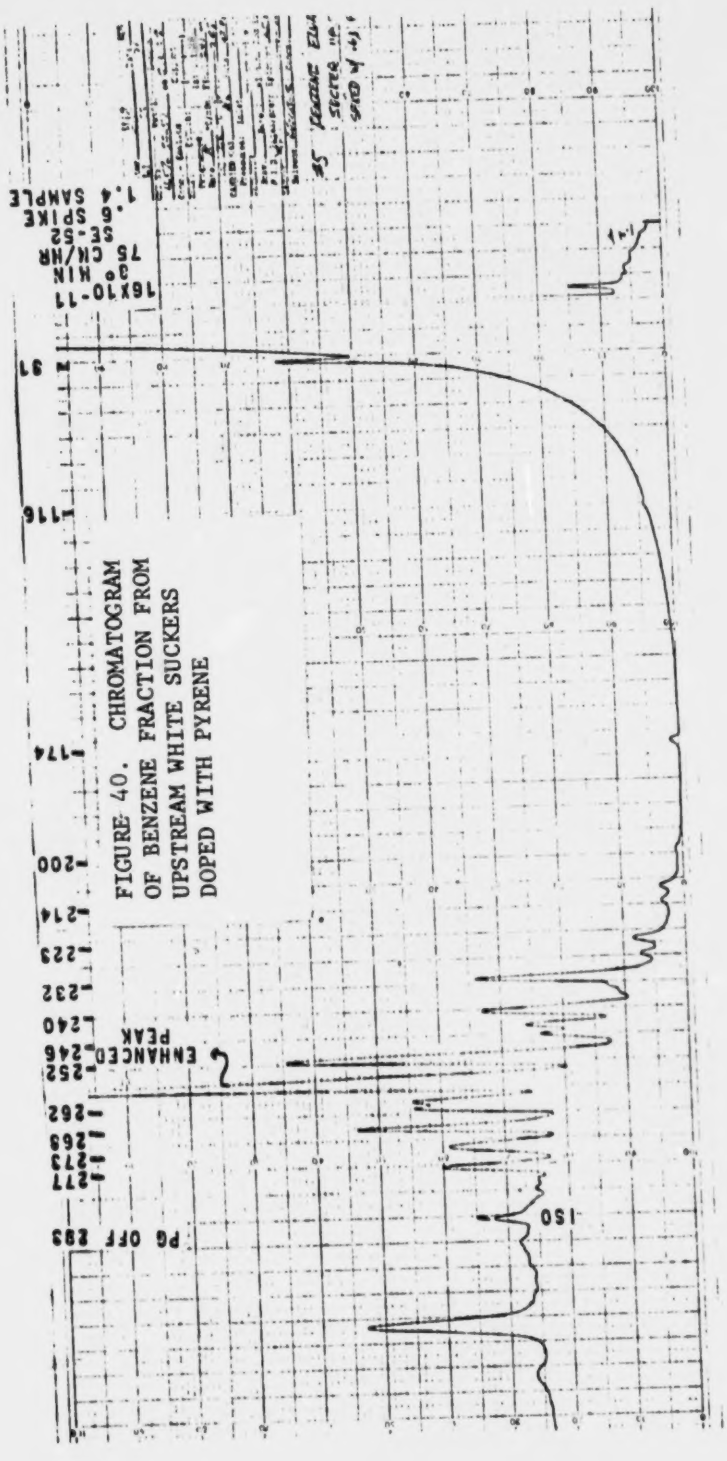


FIGURE 40. CHROMATOGRAM OF BENZENE FRACTION FROM UPSTREAM WHITE SUCKERS DOPED WITH PYRENE

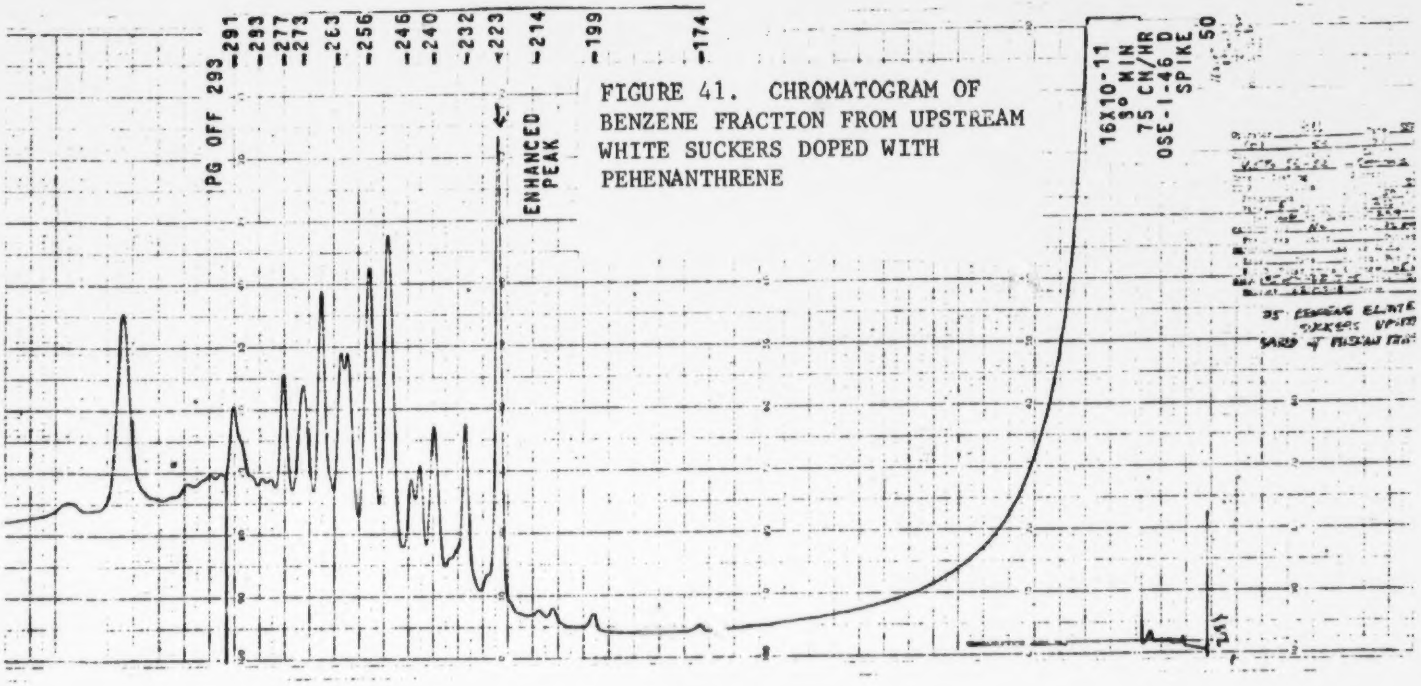


FIGURE 41. CHROMATOGRAM OF BENZENE FRACTION FROM UPSTREAM WHITE SUCKERS DOPED WITH PEHENANTHRENE

TABLE 8 Levels of Aliphatic and Aromatic Hydrocarbons in Schuylkill River Fish Collected July, 1973

Sample	Starting Sample (g)	Aliphatic Hydrocarbons (mg)	Aromatic Hydrocarbons (mg)	Aliphatic Hydrocarbons (ppm)+	Aromatic Hydrocarbons (ppm)+
Spilled oil (SCOW)	93	575*	90*	481,000	45,300
White suckers downstream	110	25	15	227	136
White suckers upstream	113	24	15	212	133
Brown bullheads downstream	116	15	9	129	78
Brown bullheads upstream	112	--**	--**		
Crappies downstream	115	8	10	70	87
Crappies upstream	116	--***	--***		

*From 1,196 g oil extract at saponification step

**Analysis abandoned due to clogged chromatographic column

***Only solid gel products on column chromatography

+Based on starting sample (fish or spilled oil)

In the analyses of the Schuylkill River fish, the infrared spectra of either the cyclohexane or the benzene-benzene/ether fractions showed qualitative reproducibility in the analyses that could be completed to this stage. All spectra indicated to a large degree the absence of absorptions corresponding to hydroxyl, primary and secondary amino, and carbonyl functional groups. This means that typical organic substances such as fats, amino acids, proteins, alcohols, carboxylic acids and esters, simple sugars and polysaccharides were largely absent in the final fractions from column chromatography.

The infrared spectra of the cyclohexane fractions of Schuylkill River fish and SCOW, along with the GC data, indicate the predominant presence of a complex mixture of saturated aliphatic hydrocarbons. The average level of aliphatics in Schuylkill River fish was 160 ppm (Table 8) vs. our average level of 13 ppm for cyclohexane eluted residues obtained from similar analytical treatment of HLFH fish (Subsection J, page 86, and Appendix V-5).

The infrared spectra of the fluorescent benzene-benzene/ether fractions indicated the possible presence of polycyclic aromatics. The weak absorptions at 3000-3100 cm^{-1} (absent from the cyclohexane eluates) suggested carbon to hydrogen bonds of the olefinic and/or aromatic type. The absorptions at 650-1250 cm^{-1} were characteristic of the complex absorption of polycyclic aromatics. Furthermore, the presence of saturated aliphatic structures was also indicated by the absorptions at 2800-3000 cm^{-1}, 1440 cm^{-1} and 1380 cm^{-1}. It was not determined whether these absorptions indicated the presence of saturated aliphatic hydrocarbons, or if the saturated aliphatic radicals were bonded to other kinds of structures. Even simple methyl ($-CH_3$) derivatives would show these absorptions. The gas chromatographic data, including the peak matching studies with polycyclic aromatics (Fig. 34) previously identified as being in oysters by Cahnmann and Kuratsune, indicated the presence of these materials in the benzene-benzene/ether fraction of Schuylkill River fish.

Cahnmann, H. and M. Kuratsune. 1957. "Determination of Polycyclic Aromatic Hydrocarbons in Oysters Collected in Polluted Water," Anal. Chem. 29:1312.

J. Studies of Fishes from Harrison Lake National Fish Hatchery

1. Test of Analytical Procedure for Polycyclic Aromatic Hydrocarbons

To provide data on fish from a relatively clean environment and to check if the polycyclic aromatics can be determined by the analytical method used, samples of channel catfish were taken from the Harrison Lake National Fish Hatchery and tainted with benzene solutions of polycyclic aromatics (Fig. 34) at the initial blending stage of the procedure. Four analyses were conducted with the added hydrocarbons at levels of zero, two, five, and ten ppm of each hydrocarbon. Two minor modifications were made in the procedure: 1) the fish powder was extracted 44-48 hours instead of 24 hours (no appreciable change in variation of oils extracted occurred, Appendix V-4), and 2) the saponification time period was reduced from 48 hours to 24 hours, which seemed to result in less troublesome gel formation.

The Harrison Lake fish are designated as "HLFH fish." The fish hatchery itself is located in Virginia at the head of Herring Creek which empties into the James River about four miles from the hatchery. The waters used by the hatchery all come from Harrison Lake which is about 190 acres in area (approximately 70 acres of open water) with no industry on its shores. Its clear waters are bordered by about 150 yards of woodland, and motorboat traffic is minimal since no public boat ramps or motorboat services are available. The traffic is basically limited to five horsepower engines which must be carried manually.

The percent yields of non-volatile residues from the extraction and saponification processes are given in Appendix V-4, and the yields of non-volatile residues from the cyclohexane and benzene/benzene-ethyl ether fractions from column chromatography are given in Appendix V-5.

2. Gas Chromatographic Studies on Benzene-Eluted Residues from Harrison Lake Fish

The residues from the benzene-benzene/ether fraction (Appendix V-5) were subjected to vapor phase chromatography

A typical chromatogram is given in Fig. 42, which was determined on fishes with 5 ppm added polycyclic aromatic hydrocarbon. Except for a large peak after the isothermal hold period, all peaks corresponded to those from the chromatogram of the standard aromatic hydrocarbon mixture (Fig. 43). Except for the addition of triphenylmethane (TPM) internal standard, the chromatogram of the benzene-benzene/ether residue from Harrison Lake fish with no added polycyclic aromatic hydrocarbons showed no peaks corresponding to these hydrocarbons (Fig. 44). All gas chromatograms of the benzene-benzene/ether fractions eluted from the Harrison Lake fish containing added polycyclic aromatic hydrocarbons showed similar patterns (Figs. 42 and 45-47).

3. Percent Recoveries of Polycyclic Aromatic Hydrocarbons from HLFH Fish

The percent recovery of polycyclic aromatic hydrocarbons from the Harrison Lake fish, which were purposely treated with known amounts of these hydrocarbons during the blending stage of the analysis, was determined. The method used involved the addition of a known quantity of an internal standard to the benzene-benzene/ether fraction from column chromatography prior to the gas chromatographic analysis.

To determine weight relationships from the internal standard, a solution of known amounts of the polycyclic aromatic hydrocarbons was mixed with a known amount of triphenylmethane internal standard. The chromatogram of this mixture is given in Fig. 43. From this chromatogram the area ratio for each hydrocarbon peak vs. the peak for TPM standard was determined, and the area ratio divided by the known weight ratio for each peak was also determined. The area ratio/weight ratio listed for each hydrocarbon in the table (Appendix V-6) represented a correction factor to be applied later to the analysis of benzene-benzene/ether eluted compounds from column chromatography.

Calculations of the percent recovery of the hydrocarbons from HLFH fish are summarized in Appendices V-7 to V-9. No calculations were made on the benzene-benzene/ether eluted material from HLFH fish with zero ppm added hydrocarbons. From the calculations in Appendices V-7 to V-9, the percent recovery of hydrocarbons ranged from 27 - 43 percent for fishes doped with 2 ppm hydrocarbon, 54 - 106 percent for fishes doped with 5 ppm hydrocarbon, and 43 - 78 percent for fishes doped with 10 ppm hydrocarbon.

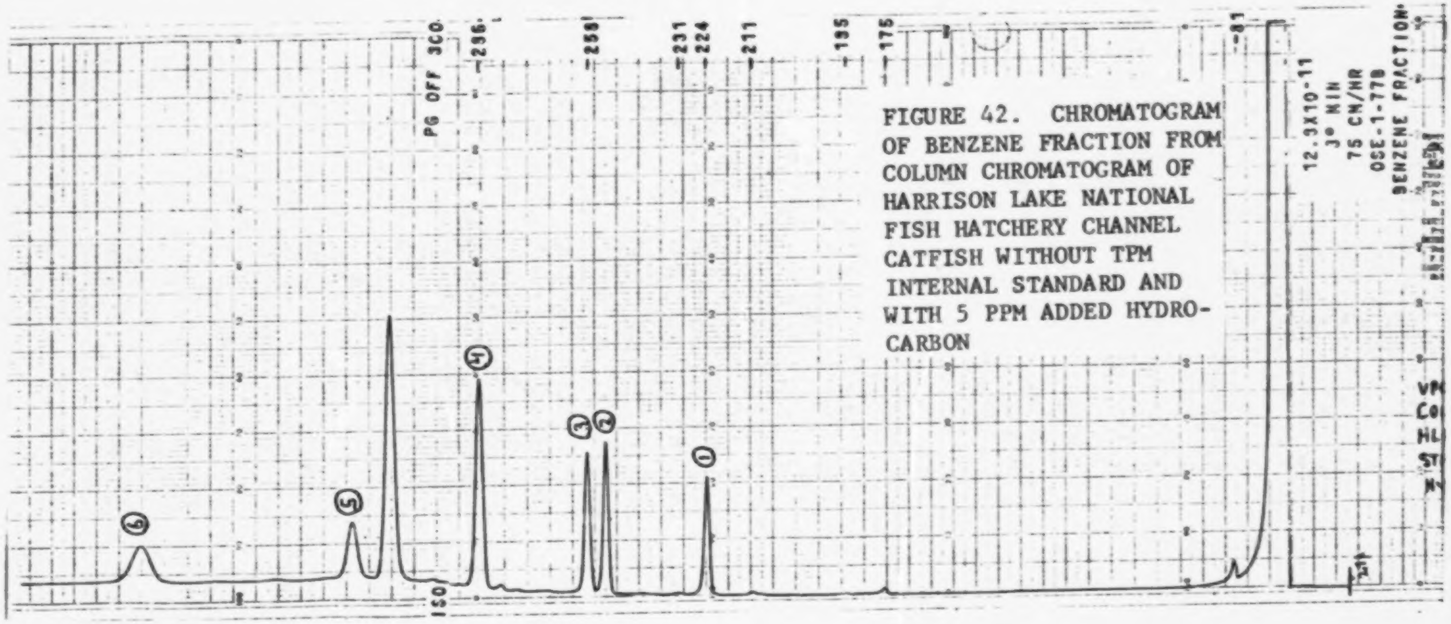


FIGURE 42. CHROMATOGRAM OF BENZENE FRACTION FROM COLUMN CHROMATOGRAM OF HARRISON LAKE NATIONAL FISH HATCHERY CHANNEL CATFISH WITHOUT TPM INTERNAL STANDARD AND WITH 5 PPM ADDED HYDROCARBON

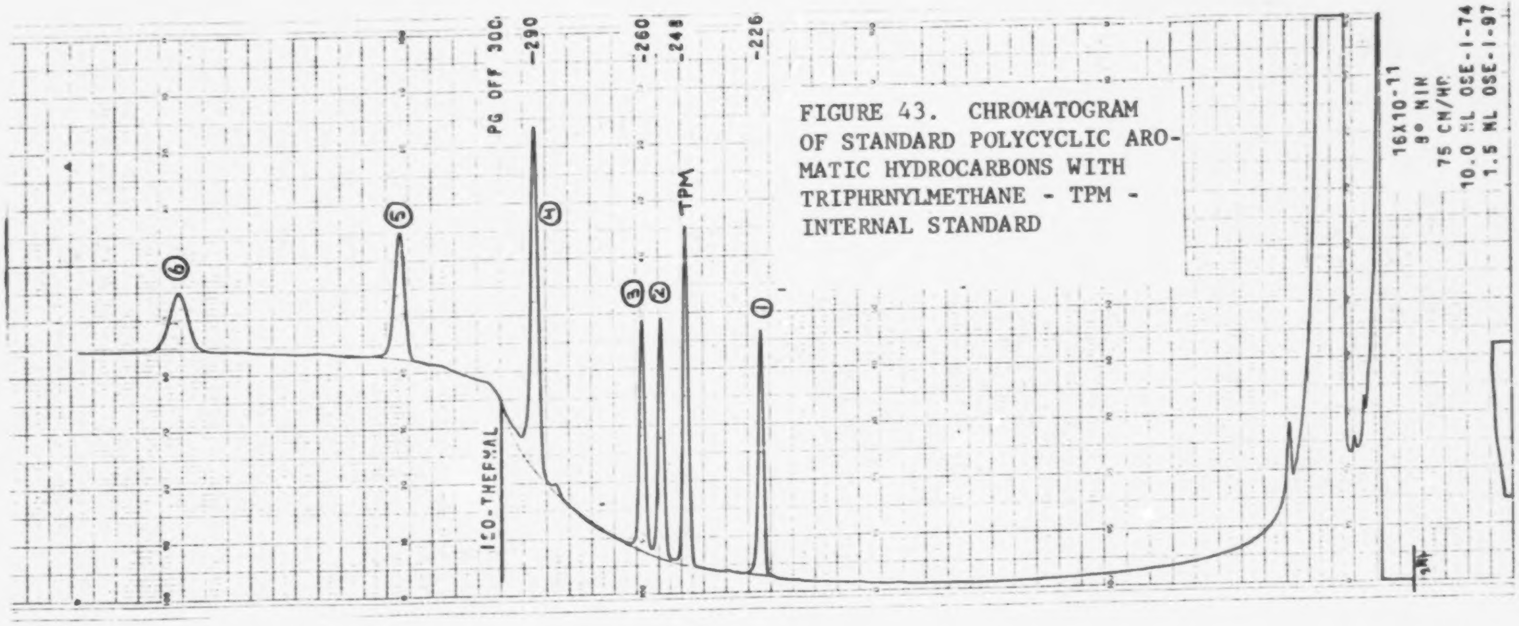


FIGURE 43. CHROMATOGRAM OF STANDARD POLYCYCLIC AROMATIC HYDROCARBONS WITH TRIPHRNYLMETHANE - TPM - INTERNAL STANDARD

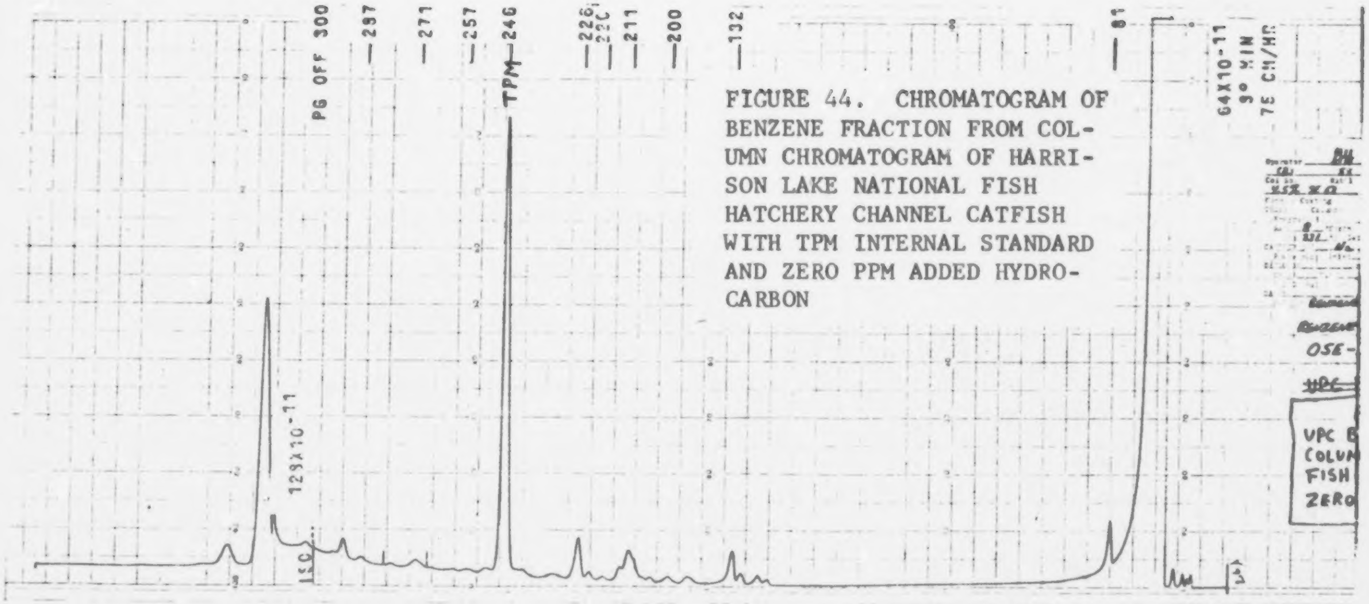


FIGURE 44. CHROMATOGRAM OF BENZENE FRACTION FROM COLUMN CHROMATOGRAM OF HARRISON LAKE NATIONAL FISH HATCHERY CHANNEL CATFISH WITH TPM INTERNAL STANDARD AND ZERO PPM ADDED HYDROCARBON

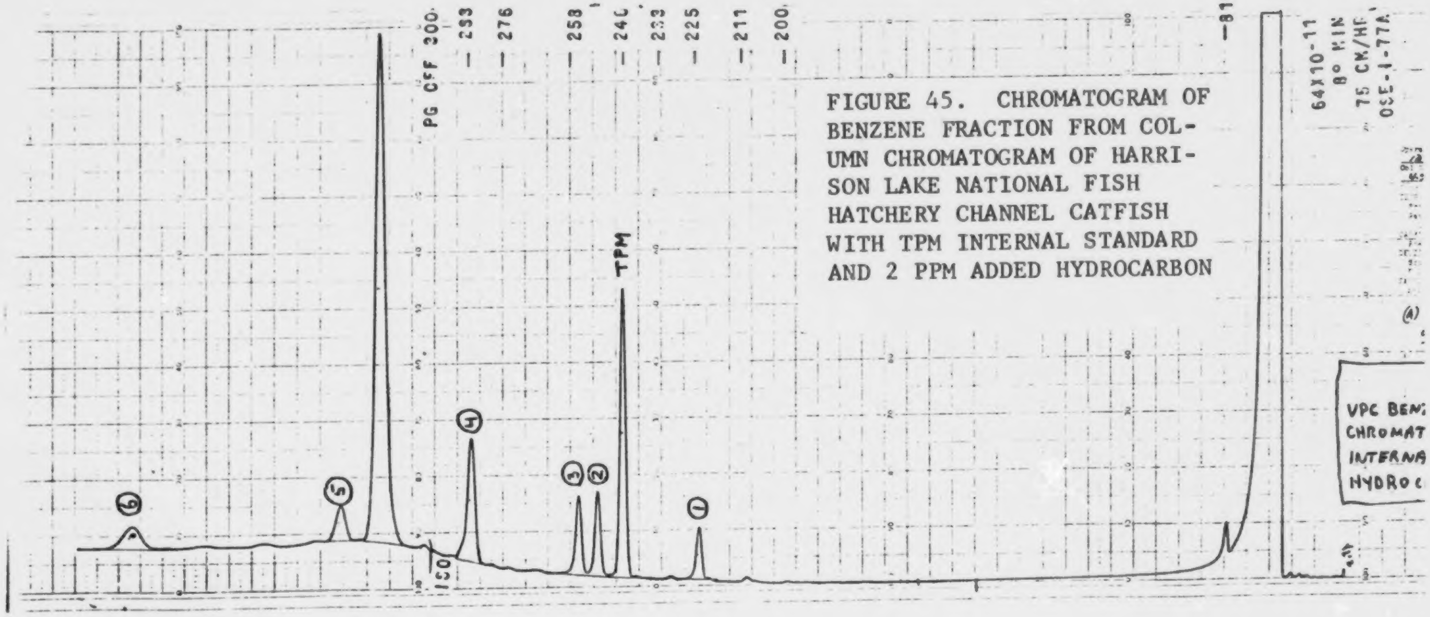


FIGURE 45. CHROMATOGRAM OF BENZENE FRACTION FROM COLUMN CHROMATOGRAM OF HARRISON LAKE NATIONAL FISH HATCHERY CHANNEL CATFISH WITH TPM INTERNAL STANDARD AND 2 PPM ADDED HYDROCARBON

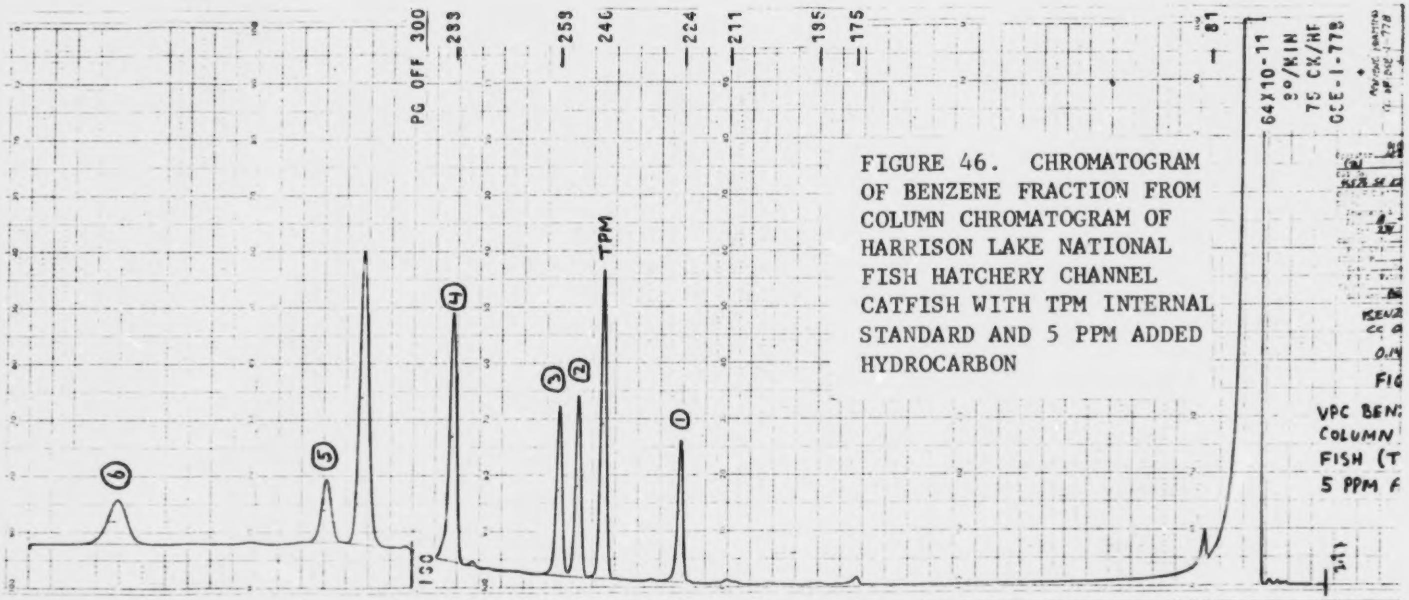


FIGURE 46. CHROMATOGRAM OF BENZENE FRACTION FROM COLUMN CHROMATOGRAM OF HARRISON LAKE NATIONAL FISH HATCHERY CHANNEL CATFISH WITH TPM INTERNAL STANDARD AND 5 PPM ADDED HYDROCARBON

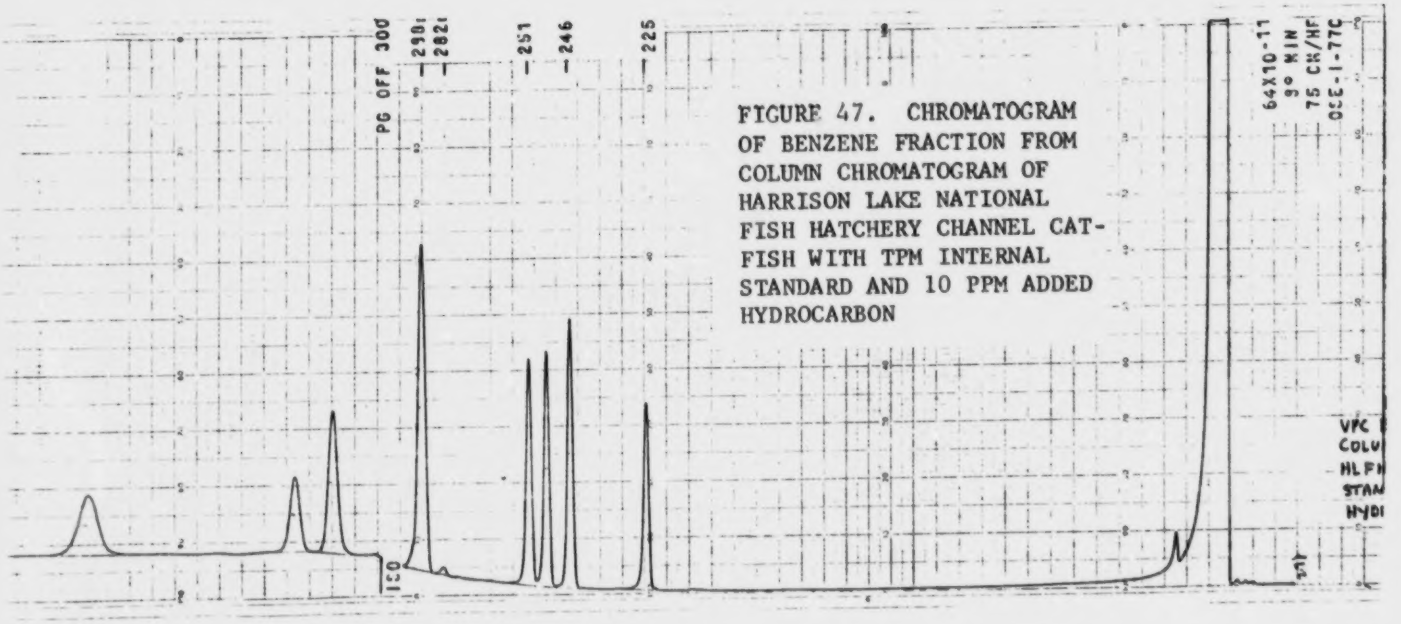


FIGURE 47. CHROMATOGRAM OF BENZENE FRACTION FROM COLUMN CHROMATOGRAM OF HARRISON LAKE NATIONAL FISH HATCHERY CHANNEL CATFISH WITH TPM INTERNAL STANDARD AND 10 PPM ADDED HYDROCARBON

The chromatograms clearly show that the analytical procedure is useful for detecting levels of polycyclic aromatics at the one ppm concentration level.

9. OTHER EFFECTS OF THE SPILL ON RIVER BIOTA

A. General Trophic-Level Interactions Among Schuylkill River Biota

The river ecosystem is composed of four basic components: abiotic substances, producer organisms, consumer organisms, and decomposer organisms. Abiotic materials, such as water, carbon dioxide, nitrogen, and phosphorous, are assimilated by two main types of producers--phytoplankton and algae attached to substrata on the river bottom. Members of this first trophic level are, in turn, grazed upon by the major components of the second trophic level--zooplankton and bottom-dwelling types of herbivores. These organisms are then preyed upon by the secondary consumers or primary carnivores that constitute the third trophic level--small adult fishes and the young of most fish species. Tertiary consumers (secondary carnivores), which are usually large fishes, prey upon the secondary consumers. Decomposers (aquatic bacteria and fungi) break down the excretory products and dead remains of both producers and consumers into abiotic substances, thus completing the trophic cycle.

Additional trophic pathways are usually superimposed upon the basic structure described above. Some organisms (omnivores) feed upon a number of trophic levels. For example, brown bullheads captured in the Schuylkill River had been feeding on small fish, dipteran larvae, and algal mats. It has also been suggested that members of the upper-trophic levels can directly utilize certain abiotic substances. Some organisms switch trophic levels as they mature and become physically able to ingest larger food items, and other organisms utilize trophic components of other ecosystems (for example, crappies observed in this study had been feeding upon flying insects).

In many lakes and ponds, the most abundant types of producers and primary consumers are phytoplankton and zooplankton, respectively. However, in relatively shallow bodies of water, such as the Schuylkill River, the bottom community (attached algae, benthic invertebrates such as Oligochaeta and Diptera larvae and pupae, bacterial flora) plays a more dominant role.

Major food items of species of fish collected during the winter of 1972-73 and the summer of 1973 were: white suckers -- Diptera larvae and pupae; brown bullheads -- Diptera larvae and pupae, small fish; crappies -- Diptera larvae and pupae, aquatic insects; bluegills -- small fish (Appendix VI-5). The importance of planktonic and benthic life forms of Diptera to the trophic needs of these fish species is apparent. The families Psychodidae, Tendipedidae, and Ceratopogonidae were the most widely represented groups of dipterans observed in stomach contents.

Stomach contents of white suckers, brown bullheads, crappies, and bluegills gave no indication of differential food habits that could be attributed to the oil spill.

B. Chlorophyll a

Average levels of total and active chlorophyll a (Appendix VI-1) increased from Monocacy Bridge station to Valley Forge Bridge station on 16 and 29 July 1972. This tends to substantiate the hypothesis of increased downstream primary productivity as suggested by pH measurement. Average levels were higher at all stations on 29 July than on 16 July.

Comparison of the ratios between pheopigment (inactive chlorophyll a) and total pigments indicated a substantially greater amount of "dead" material at Parker Ford Bridge (11.7 miles below the oil spill) on 16 July than at either Monocacy Bridge or Valley Forge Bridge (Figure 48). A slightly greater amount of pheopigment was observed at Parker Ford Bridge on 29 July than at the other stations.

Duplicate pigment measurements at the same sampling station generally indicated an acceptable degree of precision in sampling and spectrophotometric methods. The reason for the large differences between duplicate samples taken on 16 July at Valley Forge Bridge is unknown.

C. Zooplankton

Zooplankton samples taken on 16 July, 19 July, 28 November, 1 December 1972, and 14 July 1973 (Appendix VI-2) were generally similar at upstream and downstream stations. Members of the groups Cladocera (water fleas), Copepoda (copepods), and Tendipedidae (midges) were dominant forms throughout much of the study.

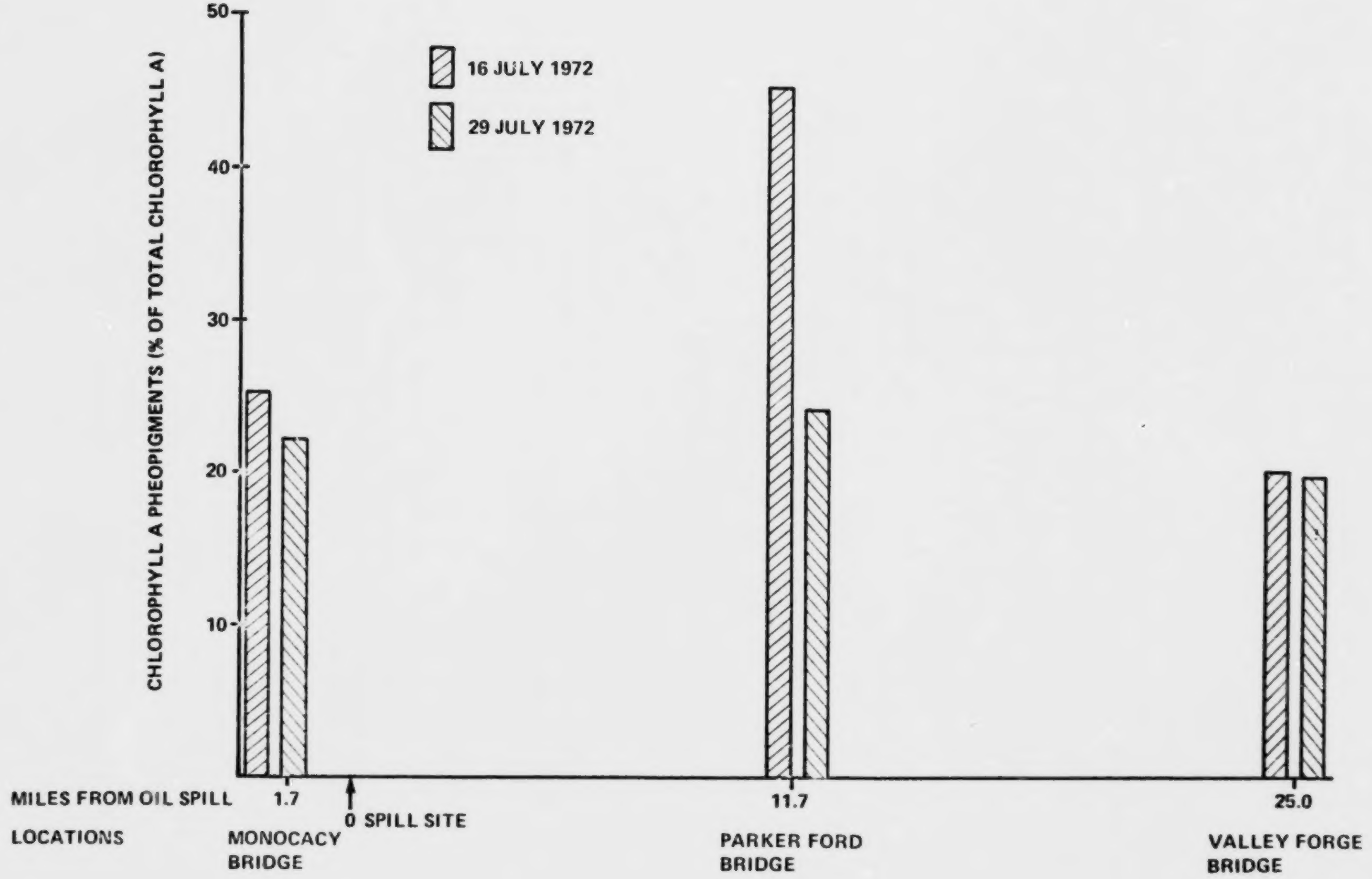


FIGURE 48 CHLOROPHYLL *a* PHEOPIGMENTS OF SCHUYLKILL RIVER WATER DURING JULY 1972

Ranges of abundance of these groups shortly after the oil spill (Figure 49) did not indicate differences between upstream and downstream stations that can be attributed to the oil spill. All three taxons exhibited greater abundance at Parker Ford Bridge station than at the upstream control station (Monocacy Bridge).

Major taxon diversity fluctuated between 6 and 10 during the study. Most taxons exhibited sharply reduced numbers during fall and winter. Lesser numbers of Cladocera, Copepoda, and Tendipedidae were observed in the summer of 1973 than during the summer of 1972.

D. Benthic Macrofauna

Larvae of the families Hydropsychidae (net-building caddis flies) and Psephenidae (water pennies) decreased in abundance in the area of the river directly below the oil spill and did not increase to their former production levels during the summer of 1972. Both groups are tolerant of rapid stream velocities and were collected in Perkiomen Creek, a small tributary emptying into the Schuylkill River between Phoenixville and Norristown, during and after the flooding caused by Tropical Storm Agnes. Therefore, it is likely that their scarcity in the Schuylkill was caused by the presence of oil rather than by the flood conditions. The food-gathering nets of many caddis fly larvae were visibly coated with oil. This may have reduced feeding efficiency. Water penny larvae breathe by ventral abdominal gills which rest directly against the rock surfaces upon which the animals attach. Any oil adhering to the rocks could conceivably have interfered with normal respiratory processes.

Quantitative sampling efforts directly after the oil spill were unsuccessful because of high-water conditions and lack of familiarity with the more suitable habitats of the river. Macrofauna samples collected on 29 November 1972 and 28 July 1973 (Appendix VI-3) exhibited no apparent variation among stations that can be attributed to the oil spill.

Ranges of abundance of the two dominant macrofaunal taxons (Figure 50) indicate that Oligochaeta (represented primarily by sludge worms of the genus Tubifex) were more abundant at both the Monocacy stations (above the oil spill) and the Parker Ford stations (10.6 to 12.5 miles downstream from the spill) than at the Douglassville stations (0.4 to 2.3 miles directly below the spill), and that numbers of Tendipedidae observed at the Monocacy and Douglassville stations did not differ greatly. Parker Ford stations were not

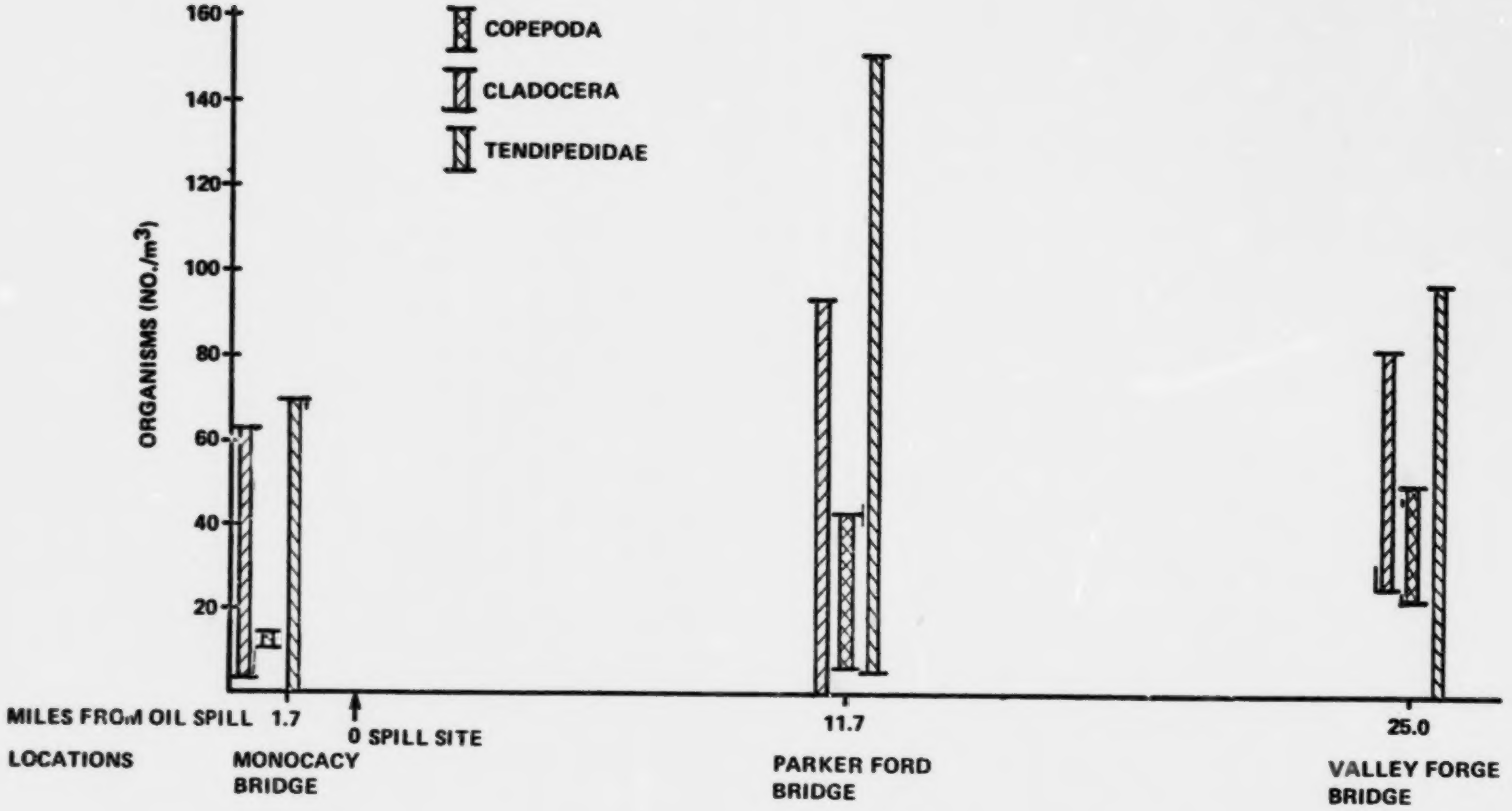


FIGURE 49 RANGES OF ABUNDANCE OF THREE DOMINANT ZOOPLANKTON TAXONS COLLECTED ON 28 JULY AND 29 NOVEMBER 1972 IN THE SCHUYLKILL RIVER

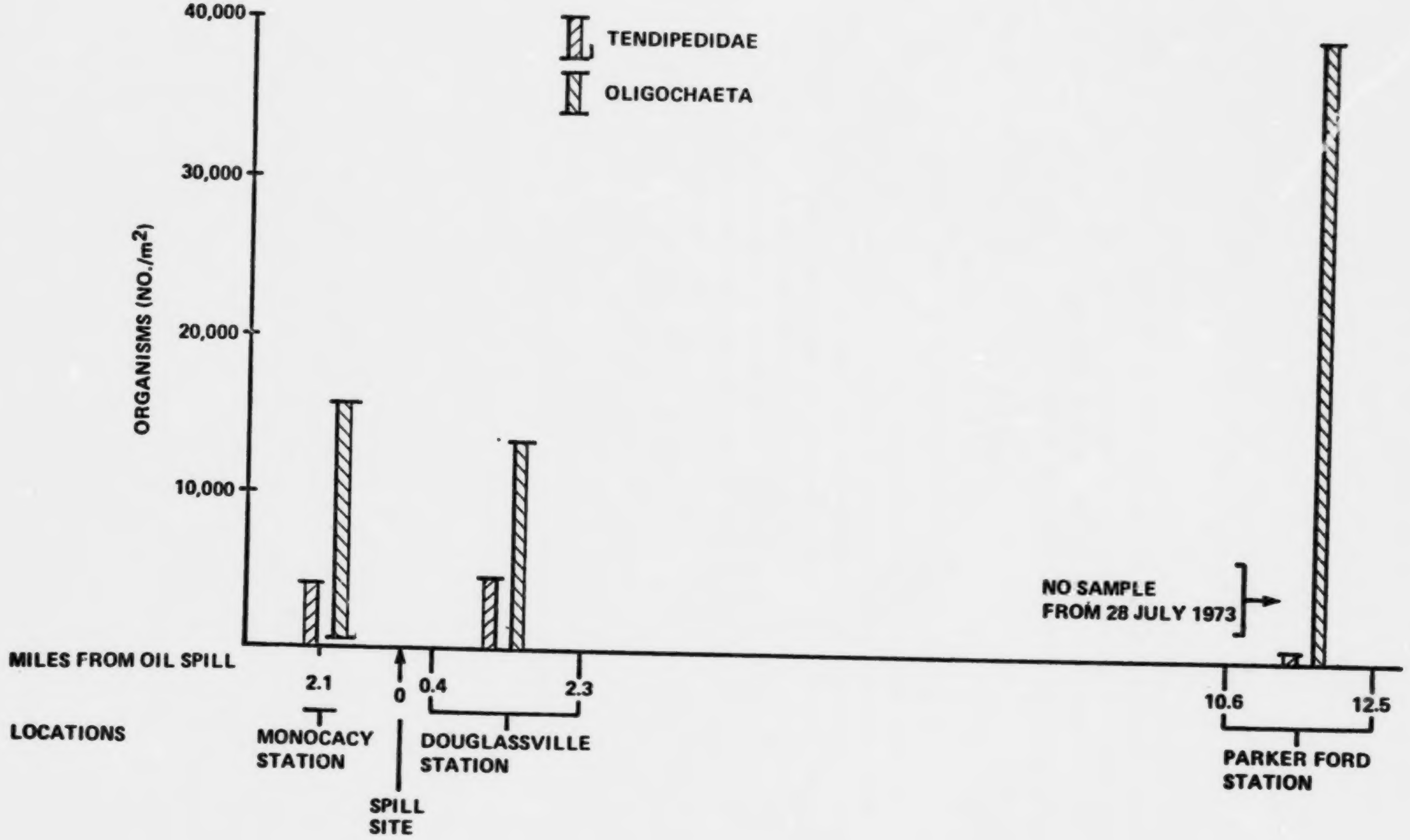


FIGURE 50. RANGES OF ABUNDANCE OF TWO DOMINANT MACROFAUNAL TAXONS COLLECTED ON 29 NOVEMBER 1972 AND 28 JULY 1973 IN THE SCHUYLKILL RIVER

sampled on 28 July 1973. Tendipedidae were commonly encountered at the other sampling stations on that date. Since both Tubifex and Tendipedidae are biological indicators that are resistant to most forms of pollution (Rounsefell and Everhart, 1953), the most likely result of the oil spill on the bottom community might be expected to be elevated numbers of both taxons in relation to other organisms directly below the spill at the Douglassville stations. This was not the case.

Major taxon diversity at the sampling sites ranged from 0 - 7 during the study (Appendix VI-3). Oligochaeta were more abundant than Tendipedidae on 29 November 1972. This relationship was reversed on 28 July 1973 presumably due, in part, to the onset of the midge reproductive season.

E. Bacteria

Bacteria counts of river sediment were taken on 17, 23, and 30 July 1972 and are shown in Appendix VI-4. On each collection date, the greatest numbers of casein splitters, glucose fermenters, and sulfate fermenters were found at the Parker Ford Bridge station. The generally low counts of glucose fermenters could indicate little recent addition of carbohydrate-like pollution to the river. Similarly, low numbers of sulfate fermenters may be due to relatively aerated conditions in the river bottom or to inactivation of the samples by air after sampling.

Contamination of the agar medium prevented estimation of the important hydrocarbon oxidizers on 17 and 23 July. However, on 30 July these bacteria were at least twice as abundant in the Parker Ford Bridge area than at the other stations.

Standard plate counts (Table 23) also revealed highest bacteria counts in the Parker Ford Bridge area on all sampling dates.

F. Community Metabolism

Suitability of oxygen data (Appendix I-1) for treatment by diurnal-curve techniques was determined. Data collected on 16 and 29 July 1972 were not usable since normal predawn decreases in

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Rounsefell, G. A. and W. H. Everhart. 1953. Fishery Science: Its Methods and Applications. J. Wiley and Sons, London. 444p.

oxygen concentrations, from which estimates of community respiration are derived, did not occur.

Oxygen data for 30 July 1972 and diurnal-curve analysis are presented in Figures 51 and 52. Community respiration and gross primary production were slightly higher at Parker Ford Bridge than upstream at Monocacy Bridge. Community respiration at both sampling stations was relatively high as compared to several river systems described by Odum (1956, Table 2). Both P/R ratios were just over 1.0, indicating an autotropic river system in which in-situ primary production slightly exceeds community respiration.

Biochemical oxygen demand (BOD) measurements taken during the summer of 1972 (Appendix I-2) ranged from 0.4 to 4.2 ppm. Highest levels were usually observed in the Douglassville Bridge - Parker Ford Bridge length of the river (0.7 to 11.7 miles below the oil spill).

The importance of the bottom community in the Schuylkill is evidenced by comparing biochemical-oxygen-demand of the river water to estimates of community respiration obtained by the diurnal-curve techniques. BOD, which measures respiration of only the planktonic flora and fauna of the river, was only 0.4 to 4.2 ppm oxygen over a five-day period. However, total community respiration, including that of the bottom community, as determined by diurnal-curve techniques, was approximately 25 ppm oxygen during a single 24-hour cycle.

10. CLEANUP IMPACT AND EFFECTIVENESS

A. A major portion of the oil swept from the pits of Berk Associates was filtered from the rising flood waters by land vegetation or deposited on the river's banks and proximal areas. Apparently only a small amount of oil was carried directly into the river basin.

It is likely that much of the oil that was carried into the river basin combined with the heavy silt and clay load that characterized the flooding river and was rapidly carried downstream toward Delaware Bay. No large masses of oil were observed during bottom

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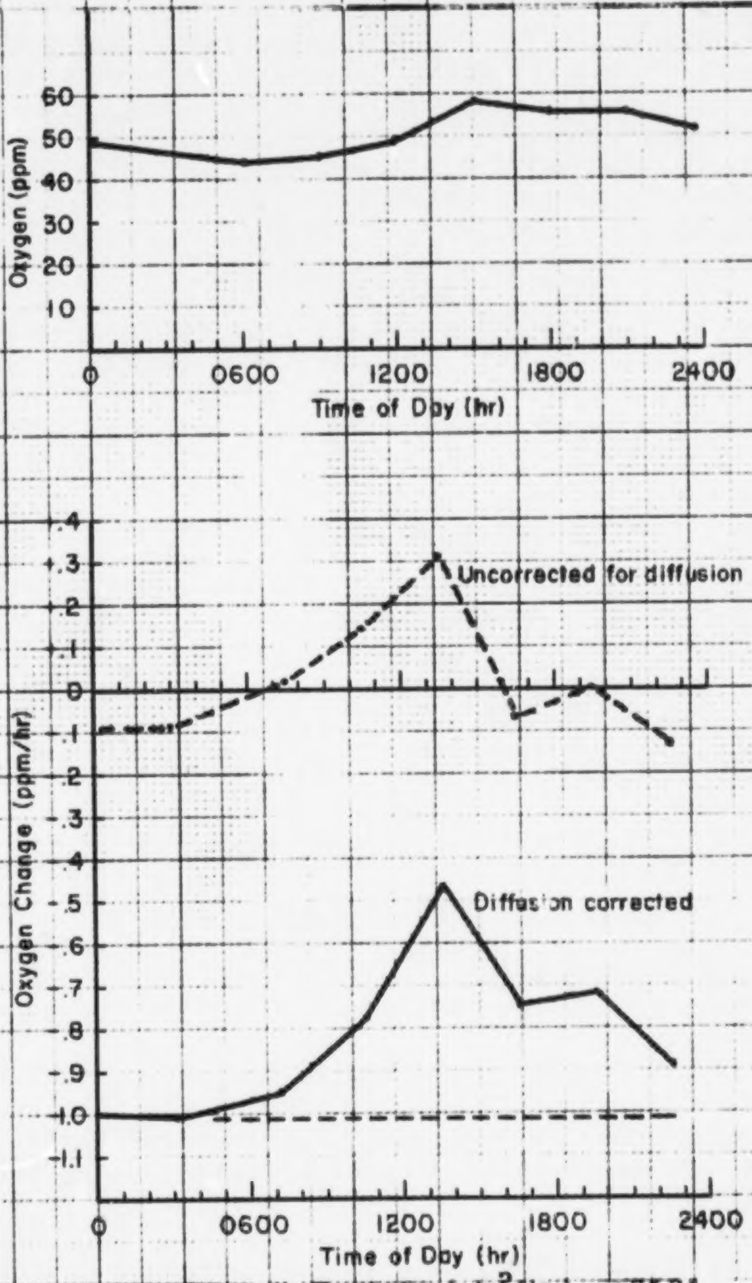
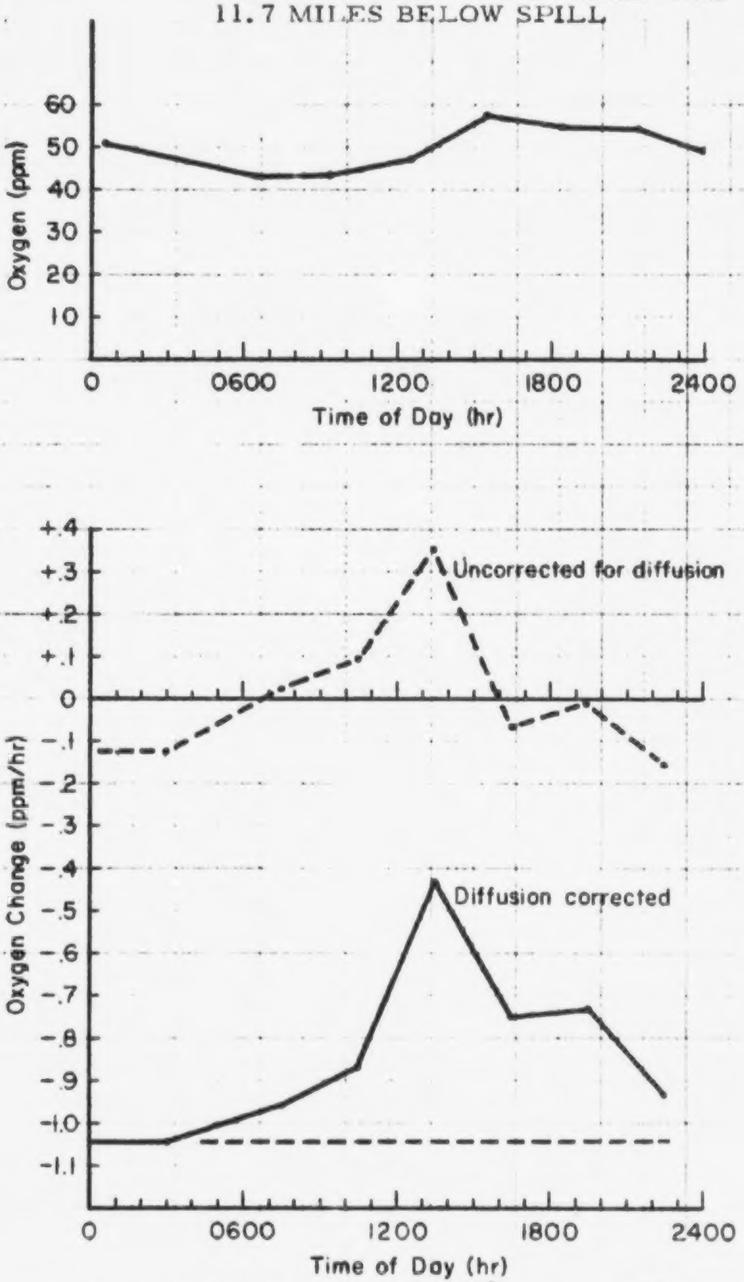
Odum, H. T. 1956. "Primary Production in Flowing Waters," Limno. Ocean. 1:102-117.

FIGURE 51. DAILY OXYGEN METABOLISM OF SCHUYLKILL RIVER BIOTA ON 30 JULY 1972 AT MONOCACY BRIDGE 17 MILES ABOVE SPILL



Community Respiration (g/m^2/day) = 24.24
Gross Primary Production (g/m^2/day) = 25.00
P/R ratio = 1.03

FIGURE 52. DAILY OXYGEN METABOLISM OF SCHUYLKILL RIVER BIOTA ON 30 JULY 1972 AT PARKER FORD BRIDGE 11.7 MILES BELOW SPILL



Community Respiration ($g/m^2/day$) = 25.20
Gross Primary Production ($g/m^2/day$) = 27.50
P/R ratio = 1.09

sampling operations. Most of the silt and clay particles upon which hydrocarbon and heavy metals precipitate were washed away by the flood waters. Only a sand-pebble substratum remained. Chemical analysis of heavy metal and hydrocarbon concentrations of the bottom indicated that there was some oil contamination of the river bottom below the spill.

Cleanup of the river bottom was considered unnecessary due to the high cost. The inefficiency of the operation would have only served to redistribute much of the oil that had been deposited on the river bottom.

B. Oil that was deposited directly on land had to be physically removed. Heavy metal constituents of the oil were likely to persist through time. Workmen had to avoid accidental oral intake of the oil (Physical contact with the metals' components is not a problem). Burning of oil will vaporize heavy metals and result in a potential hazard to workmen and to the surrounding environment. Burning should never be attempted. Vaporization of low-boiling aromatic hydrocarbon (another component of the oil) caused a noticeable "oily" smell in the affected area. Toxic materials will evaporate and be oxidized and decomposed with time. However, they are considered a health hazard to men subjected to chronic exposure through inhalation. Care was taken not to bury removed oil where contamination to ground water or livestock might occur.

C. Oil deposited on vegetation (leaves, grasses, etc.) adhered tightly to the plants after a period of consolidation. Rainfall or falling of leaves into the river resulted in only small amounts of heavy metals and remaining hydrocarbons (most toxic hydrocarbons had already been evaporated or decomposed) going into solution. Hence, periodic precipitation and gradual fall of leaves into the river unlikely caused major human health problems. Any hosing of vegetation during a short time period or before low-boiling aromatic hydrocarbons had evaporated or decomposed would have resulted in a more acute problem of river pollution than doing nothing. Primary cleanup operations performed for the removal of vegetation resulted in the following:

1) Only trees, shrubs, and branches in the most heavily polluted areas were removed in order to leave a root system to prevent bank erosion.

2) "Quick-cover," fast-growing grass was used to prevent erosion.

3) Angled booms were placed at strategic locations along the river to collect floating leaves and oil slicks. Booms were placed in slowly moving sections of the river and kept in operation until most oil-covered leaves had dropped from the banks. Angled booms also directed floating oil to the bank at water velocities of less than 2 knots. Trucks were permanently at locations to suck leaves and oil from the junctions of the booms and riverbank.

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Ocean Science and Engineering, Inc., gratefully acknowledges the hard work and dedication of the scientists and technicians who contributed to this study.

Mr. Charles R. Mainville was the Program Manager.

Dr. Charles R. Curtis, Associate Professor of Plant Pathology at the University of Maryland, conducted the investigations of the effects of the spill on vegetation.

Techniques for the analysis of hydrocarbons in vertebrate fishes were developed by Professor Trevor Hill of the College of William and Mary. Dr. Hill was assisted in his work by Messrs. William S. Eck, Robert Huggett, and Gerry Lasser.

Mr. Robert Huggett of the Virginia Institute of Marine Science performed the heavy metaos analyses of the oil, sediments, and organisms.

Biological analyses and water-quality investigations were performed by Dr. Curt D. Rose, Head of the Shellfish Division of the University of Maryland's Center for Environmental and Estuarine Studies. Dr. Rose was assisted by Messrs. Rodgers Huff, Joseph Ustach, Bud Millsaps, Dan Terlizzi, and Don Meritt.

Messrs. Michael Clark, Larry Kingsbury, and Roy L. Rice of OSE performed much of the field work during the program.

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GLOSSARY

Common Name	Biological Name
Birch	*Betula sp*.
Black walnut	*Juglans nigra L*.
Bluegill	*Lepomis macrochirus*
Brown bullheads	*Ictalurus nebulosus*
Channel catfish	*Ictalurus punctatus*
Crappies	*Pomoxis sp*.
Elm	*Ulmus sp*.
Golden shiver	*Notemigonus crysoleucas*
Hickory	*Carya sp*.
Maple	*Acer sp*.
Net building caddis flies	*Hydropsychidae*
Oak	*Quercus sp*.
Sassafras	*Sassafras albidium*
Sycamore	*Platanus occidentalis L*.
Tree of heaven	*Ailanthus altissima*
Tuliptree	*Liriodendron tulipifers L*.
Water pennies	*Psephenidae*
White suckers	*Catostomus commersoni*
Wild cherry	*Prunus sp*.

APPENDIX I DATA FROM ANALYSES OF RIVER WATER

Appendix I-1. Twenty-four (24) hour temperature and dissolved oxygen
July 1972

Above Spill

Below Spill

16 July 1972

Monocacy

Parker Ford

Time	Temp. (°C)	Dissolved O_2 (ppm)	Time	Temp. (°C)	Dissolved O_2 (ppm)
0025	24	5.2	0000	26	5.3
0630	24	5.7	0600	25	5.8
0930	25	5.9	0900	25	5.8
1230	27	6.1	0200	27	6.3
1530	27	6.2	1600	28	6.4
2020	25	6.2	1830	28	6.4

29 July 1972

Monocacy

Parker Ford

Time	Temp. (°C)	Dissolved O_2 (ppm)	Time	Temp. (°C)	Dissolved O_2 (ppm)
0100	23	5.2	0030	23	5.7
0640	23	6.2	0625	23	7.0
0950	24	6.3	0925	24	7.1
1310	23	7.5	1245	24	7.6
1905	24	7.6	1235	24	8.0

Appendix I-1. (continued)

Above Spill Below Spill

30 July 1972

Monocacy			Parker Ford		
Time	Temp. (°C)	Dissolved O_2 (ppm)	Time	Temp. (°C)	Dissolved O_2 (ppm)
0000	21	4.9	0030	23	5.1
0600	21	4.4	0630	23	4.4
0900	21	4.5	0930	23	4.4
1200	21	4.9	1230	23	4.7
1500	21	5.8	1530	23	5.7
1800	21	5.6	1830	23	5.5
2100	21	5.6	2130	23	5.5
2400	21	5.2	2430	23	5.0

Appendix I-2. Biochemical oxygen demand, chemical oxygen demand, and M.O. alkalinity of Schuylkill River water above and below spill site in July 1972

Station	BOD (ppm-5 day) 3 July 1972	COD (ppm)	M.O. Alkalinity (ppm $CaCO_3$)
Above Spill			
Monocacy	1.1	6.71	50
Below Spill			
Douglassville Br.	0.9	7.38	54
Parker Ford Br.	1.5	9.40	53
Spring City Br.	1.5	15.44	56
Rt. 113 Br.	1.3	10.07	52
Valley Forge Br.	1.4	15.10	52
Falls Br. (Phila.)	1.3	10.74	55
	11 July 1972		
Above Spill			
Monocacy	1.0	5.59	--
Below Spill			
Douglassville Br.	0.9	5.38	--
Parker Ford Br.	0.4	10.40	--
Valley Forge Br.	0.8	4.97	--

Appendix I-2. (continued)

	18 July 1972		
Above Spill			
Monocacy Br.	0.6	9.27	70
Below Spill			
Douglassville Br.	0.9	10.50	68
Parker Ford Br.	0.7	16.10	72
Valley Forge Br.	0.5	9.67	67
	25 July 1972		
Above Spill			
Monocacy Br.	1.8	7.56	73
Below Spill			
Douglassville Br.	2.7	11.10	82
Parkerford Br.	1.8	7.96	84
Valley Forge Br.	1.6	11.10	76
	1 August 1972		
Above Spill			
Monocacy Br.	1.9	8.97	68
Below Spill			
Douglassville Br.	4.2	11.30	78
Parkerford Br.	1.7	6.24	76
Valley Forge Br.	1.3	6.63	78

Appendix I-3. Hydrogen-ion concentration in Schuylkill River water 12 July - 5 August 1972

Date	Stations			
	Above Spill	Below Spill		
	Monocacy	Douglassville	Parker Ford	Valley Forge
July 12	7.4	7.4	7.4	7.5
July 13	7.4	7.3	7.4	7.7
July 14	7.2	7.2	7.2	7.3
July 15	7.4	7.4	7.4	7.4
July 16	--	7.5	7.4	7.7
July 17	7.0	7.0	7.0	7.3
July 18	7.1	7.1	7.0	7.2
July 19	7.2	7.2	7.0	7.2
July 20	7.2	7.1	7.2	7.2
July 21	7.1	7.2	7.1	7.1
July 22	7.2	7.2	7.2	7.2
July 23	7.2	7.2	7.2	7.3
July 24	7.3	7.3	7.4	7.8
July 25	7.2	7.2	7.2	7.6
July 26	7.2	7.2	7.2	7.2
July 27	7.2	7.2	7.2	7.3
July 28	7.2	7.2	7.2	7.2
July 29	7.2	7.2	7.2	7.6
July 30	7.2	7.2	7.2	7.8
July 31	7.2	7.2	7.2	7.6

Appendix I-3. (continued)

Date	Stations			
	Monocacy	Douglassville	Parker Ford	Valley Forge
August 1	7.2	7.2	7.2	7.4
August 2	7.3	7.2	7.2	7.4
August 3	7.2	7.1	7.2	7.3
August 4	7.1	--	7.2	7.3
August 5	7.2	--	7.5	--

[1] All readings were taken during the day and, therefore, represent maximum daily values.

APPENDIX II DATA FROM HEAVY METALS ANALYSES OF RIVER WATER AND SEDIMENTS

Appendix II-1. Concentrations of lead, zinc, cadmium, and copper in Schuylkill River water 3 July - 4 August 1972

STATION	HEAVY METAL CONCENTRATION (ppm)			
	Lead	Zinc	Cadmium	Copper
3 July				
Monocacy Farm Bridge	0.015	0.01	0.002	0.05
Douglassville Bridge	0.014	0.025	0.002	0.05
Parker Ford Bridge	0.014	0.01	0.002	0.05
Spring City/Royersford Br.	0.011	0.03	0.002	0.05
Route 113 Bridge	0.039	0.070	0.002	0.05
Valley Forge Bridge	0.033	0.03	0.002	0.05
Falls Bridge	0.018	0.025	0.002	0.05
4 July				
Monocacy Farm	0.004	0.01	0.002	0.05
Douglassville Bridge	0.038	0.05	0.002	0.05
Parker Ford Br., Sample 1	0.023	0.04	0.002	0.05
Parker Ford Br., Sample 2	0.040	0.02	0.002	0.05
Spring City/Royersford Br.	0.003	0.01	0.002	0.05
Route 113 Bridge	0.024	0.04	0.002	0.05
Valley Forge Bridge	0.010	0.02	0.002	0.05
Falls Bridge	0.009	0.01	0.002	0.05
5 July				
Monocacy Farm, Sample 1	0.004	0.03	0.002	0.05
Monocacy Farm, Sample 2	0.003	0.03	0.002	0.05
Douglassville Bridge	0.086	0.05	0.002	0.05

Appendix II-1. (continued)

STATION	HEAVY METAL CONCENTRATION (ppm)			
	Lead	Zinc	Cadmium	Copper
5 July (contd)				
Parker Ford Bridge	0.004	lost	0.002	0.05
Route 113 Bridge	0.046	0.04	0.002	0.05
Valley Forge Bridge	0.016	0.01	0.002	0.05
Falls Bridge	0.011	0.01	0.002	0.05
6 July				
Monocacy Farm, Sample 1	0.002	0.02	0.002	0.05
Monocacy Farm, Sample 2	0.002	0.02	0.002	0.05
Douglassville Bridge	0.040	0.01	0.002	0.05
Parker Ford Bridge	0.029	0.03	0.002	0.05
Spring City/Royersford Br.	0.011	0.04	0.002	0.05
Route 113 Bridge	0.005	0.02	0.002	0.05
Valley Forge Bridge	0.016	0.04	0.002	0.05
Falls Bridge	0.012	0.01	0.002	0.05
7 July				
Monocacy Farm, Sample 1	0.004	0.05	0.002	0.05
Monocacy Farm, Sample 2	0.002	0.02	0.002	0.05
Douglassville Bridge	0.041	0.06	0.002	0.05
Parker Ford Bridge	0.015	0.07	0.002	0.05
Spring City/Royersford Br.	0.019	0.08	0.002	0.05
Route 113 Bridge	0.018	0.05	0.002	0.05
Valley Forge Bridge	0.019	0.01	0.002	0.05
Falls Bridge	0.015	0.04	0.002	0.05

Appendix II-1. (continued)

STATION	HEAVY METAL CONCENTRATION (ppm)			
	Lead	Zinc	Cadmium	Copper
8 July				
Monocacy Farm, Sample 1	0.006	0.04	0.002	0.05
Monocacy Farm, Sample 2	0.004	0.02	0.002	0.05
Douglassville Bridge	0.018	0.05	0.002	0.05
Parker Ford Bridge	0.010	0.03	0.002	0.05
Valley Forge Bridge	0.028	0.07	0.002	0.05
9 July				
Monocacy Farm	0.005	0.010	0.002	0.05
Douglassville Bridge	0.015	0.06	0.002	0.05
Parker Ford Bridge	0.013	0.06	0.002	0.05
Valley Forge Bridge	0.015	0.01	0.002	0.05
10 July				
Monocacy Farm	0.002	0.010	0.002	0.05
Douglassville Bridge	0.008	0.037	0.002	0.05
Parker Ford Bridge	0.005	0.010	0.002	0.05
Valley Forge Bridge	0.006	0.012	0.002	0.05
11 July				
Monocacy Farm	0.002	0.018	0.002	0.05
Douglassville Bridge	0.010	0.031	0.002	0.05
Parker Ford Bridge	0.010	0.018	0.002	0.05
Valley Forge Bridge	0.014	0.010	0.002	0.05
12 July				
Monocacy Farm	0.002	0.010	0.002	0.05
Douglassville Bridge	0.006	0.031	0.002	0.05

Appendix II-1. (continued)

STATION	HEAVY METAL CONCENTRATION (ppm)			
	Lead	Zinc	Cadmium	Copper
12 July (contd)				
Parker Ford Bridge	0.017	0.018	0.002	0.05
Valley Forge Bridge	0.016	0.010	0.002	0.05
13 July				
Monocacy Farm	0.003	0.004	0.001	0.03
Douglassville Bridge	0.006	0.016	0.001	0.03
Parker Ford Bridge	0.008	0.029	0.001	0.03
Valley Forge Bridge	0.006	0.004	0.001	0.03
14 July				
Monocacy Farm	0.005	0.009	0.001	0.03
Douglassville Bridge	0.013	0.026	0.001	0.03
Parker Ford Bridge	0.010	0.016	0.001	0.03
Valley Forge Bridge	0.011	0.009	0.001	0.03
15 July				
Monocacy Bridge	0.002	0.015	0.001	0.03
Douglassville Bridge	0.007	0.029	0.001	0.03
Parker Ford Bridge	0.005	0.015	0.001	0.03
Valley Forge Bridge	0.002	0.011	0.001	0.03
16 July				
Monocacy Bridge	0.005	0.011	0.001	0.03
Douglassville Bridge	0.003	0.009	0.001	0.03
Parker Ford Bridge	0.005	0.015	0.001	0.03
Valley Forge Bridge	0.006	0.018	0.001	0.03

Appendix II-1. (continued)

STATION	HEAVY METAL CONCENTRATION (ppm)			
	Lead	Zinc	Cadmium	Copper
17 July				
Monocacy Bridge	0.003	0.007	0.001	0.03
Douglassville Bridge	0.003	0.007	0.001	0.03
Parker Ford Bridge	0.003	0.007	0.001	0.03
Valley Forge Bridge	0.003	0.009	0.001	0.03
18 July				
Monocacy Bridge	0.002	0.013	0.001	0.03
Douglassville Bridge	0.016	0.012	0.001	0.03
Parker Ford Bridge	0.002	0.014	0.001	0.03
Valley Forge Bridge	0.003	0.014	0.001	0.03
19 July				
Monocacy Bridge	0.001	0.013	0.001	0.03
Douglassville Bridge	0.003	0.011	0.001	0.03
Parker Ford Bridge	0.003	0.013	0.001	0.03
Valley Forge Bridge	0.002	0.012	0.001	0.03
20 July				
Monocacy Bridge	0.003	0.013	0.001	0.03
Douglassville Bridge	0.003	0.012	0.001	0.03
Parker Ford Bridge	0.002	0.013	0.001	0.03
Valley Forge Bridge	0.002	0.011	0.001	0.03
21 July				
Monocacy Bridge	0.001	0.012	0.001	0.03
Douglassville Bridge	0.002	0.014	0.001	0.03
Parker Ford Bridge	0.003	0.013	0.001	0.03
Valley Forge Bridge	0.003	0.012	0.001	0.03

Appendix II-1. (continued)

STATION	HEAVY METAL CONCENTRATION (ppm)			
	Lead	Zinc	Cadmium	Copper
22 July				
Monocacy Bridge	0.002	0.011	0.001	0.03
Douglassville B ridge	0.002	0.013	0.001	0.03
Parker Ford Bridge	0.002	0.014	0.001	0.03
Valley Forge Bridge	0.002	0.013	0.001	0.03
23, 24, 25 July				
Samples lost in shipment				
26 July				
Monocacy Bridge	0.006	0.005	0.001	0.03
Douglassville Bridge	0.009	0.007	0.001	0.03
Parker Ford Bridge	0.005	0.005	0.001	0.03
Valley Forge Bridge	0.008	0.005	0.001	0.03
27 July				
Monocacy Bridge	0.008	0.004	0.001	0.03
Douglassville Bridge	0.006	0.004	0.001	0.03
Parker Ford Bridge	0.006	0.005	0.001	0.03
Valley Forge Bridge	0.007	0.009	0.001	0.03
28 July				
Monocacy Bridge	0.005	0.003	0.001	0.03
Douglassville Bridge	0.006	0.002	0.001	0.03
Parker Ford Bridge	0.007	0.009	0.001	0.03
Valley Forge Bridge	0.007	0.011	0.001	0.03

Appendix II-1. (continued)

STATION	HEAVY METAL CONCENTRATION (ppm)			
	Lead	Zinc	Cadmium	Copper
29 July				
Monocacy Bridge	0.007	0.007	0.001	0.03
Douglassville Bridge	0.006	0.007	0.001	0.03
Parker Ford Bridge	0.006	0.009	0.001	0.03
Valley Forge Bridge	0.034	0.008	0.001	0.03
30 July				
Monocacy Bridge	0.007	0.008	0.001	0.03
Douglassville Bridge	0.006	0.008	0.001	0.03
Parker Ford Bridge	0.008	0.007	0.001	0.03
Valley Forge Bridge	0.008	0.004	0.001	0.03
31 July				
Monocacy Bridge	0.009	0.009	0.001	0.03
Douglassville Bridge	0.006	0.005	0.001	0.03
Parker Ford Bridge	0.009	0.007	0.001	0.03
Valley Forge Bridge	0.009	0.017	0.001	0.03
1 August				
Monocacy Bridge	0.001	0.013	0.001	0.03
Douglassville Bridge	0.001	0.012	0.001	0.03
Parker Ford Bridge	0.003	0.012	0.011	0.03
Valley Forge Bridge	0.001	0.012	0.001	0.03
2 August				
Monocacy Bridge	0.005	0.007	0.001	0.03
Douglassville Bridge	0.005	0.009	0.001	0.03
Parker Ford Bridge	0.007	0.012	0.003	0.03
Valley Forge Bridge	0.006	0.007	0.001	0.03

Appendix II-1. (continued)

STATION	**HEAVY METAL CONCENTRATION (ppm)**			
	Lead	**Zinc**	**Cadmium**	**Copper**
3 August				
Monocacy Bridge	0.007	0.015	0.001	0.03
Douglassville Bridge	0.007	0.015	0.001	0.03
Parker Ford Bridge	0.012	0.012	0.001	0.03
Valley Forge Bridge	0.012	0.009	0.001	0.03
4 August				
Monocacy Bridge	0.005	0.009	0.001	0.03
Douglassville Bridge	0.007	0.009	0.001	0.03
Parker Ford Bridge	0.022	0.006	0.001	0.03
Valley Forge Bridge	0.012	0.012	0.001	0.03
5 August				
Monocacy Bridge	0.006	0.012	0.001	0.03
Parker Ford Bridge	0.007	0.009	0.001	0.03

Appendix II-2. Concentrations of lead, zinc, cadmium, and copper in Schuylkill River bottom samples collected in July, 1972

STATION	Loi	Lead	Zinc	Cadmium	Copper
1 July					
12.4 miles below spill		32.5	259	0.2	45.1
12.4 miles below spill		154.0	218	0.2	32.6
11.72 miles below spill		14.2	426	0.4	30.0
11.72 miles below spill		16.9	353	0.4	47.5
2 July					
2.35 miles below spill		61.7	135	0.2	494.0
2.35 miles below spill		3.7	70	0.2	25.0
3.75 miles below spill		1.3	51	0.2	22.7
5.75 miles below spill		17.5	169	0.2	31.4
6.75 miles below spill		19.7	161	0.2	35.8
6.75 miles below spill		16.9	177	0.2	35.1
8.75 miles below spill		11.9	119	0.2	38.1
8.75 miles below spill		28.8	158	0.2	36.4
10.7 miles below spill		171.0	225	0.2	33.3
19.90 miles below spill		38.5	235	0.2	27.3
19.90 miles below spill		37.6	300	0.2	32.0
22.25 miles below spill		44.1	309	0.2	40.5
22.25 miles below spill		26.2	233	0.2	29.1
4 July					
Parker Ford Bridge		5.1	135	0.2	34.9
Parker Ford Bridge		9.3	230	0.2	23.7
Route 113 Bridge		22.1	274	0.2	28.6

Appendix II-2. (continued)

STATION	Loi	Lead	Zinc	Cadmium	Copper
5 July					
Route 113 Bridge		161.0	310	0.2	33.5
9 July					
Monocacy		395.0	416	1.3	145.0
Douglassville Bridge		14.1	101	0.2	22.5
Parker Ford Bridge		13.5	192	0.2	38.4
Valley Forge Bridge		9.2	38	0.2	11.9
11 July					
Monocacy Farm	16.70%	304	373	1.7	161
Douglassville Bridge	10.08%	372	312	2.1	113
Valley Forge Bridge	12.42%	124	162	1.5	42.7
15 July					
Douglassville Bridge	9.90%	32.1	62.1	1.2	25.9
Parker Ford Bridge	26.31%	2210.0	656	2.6	193
Valley Forge Bridge	5.71%	39.2	144	3.1	22.0

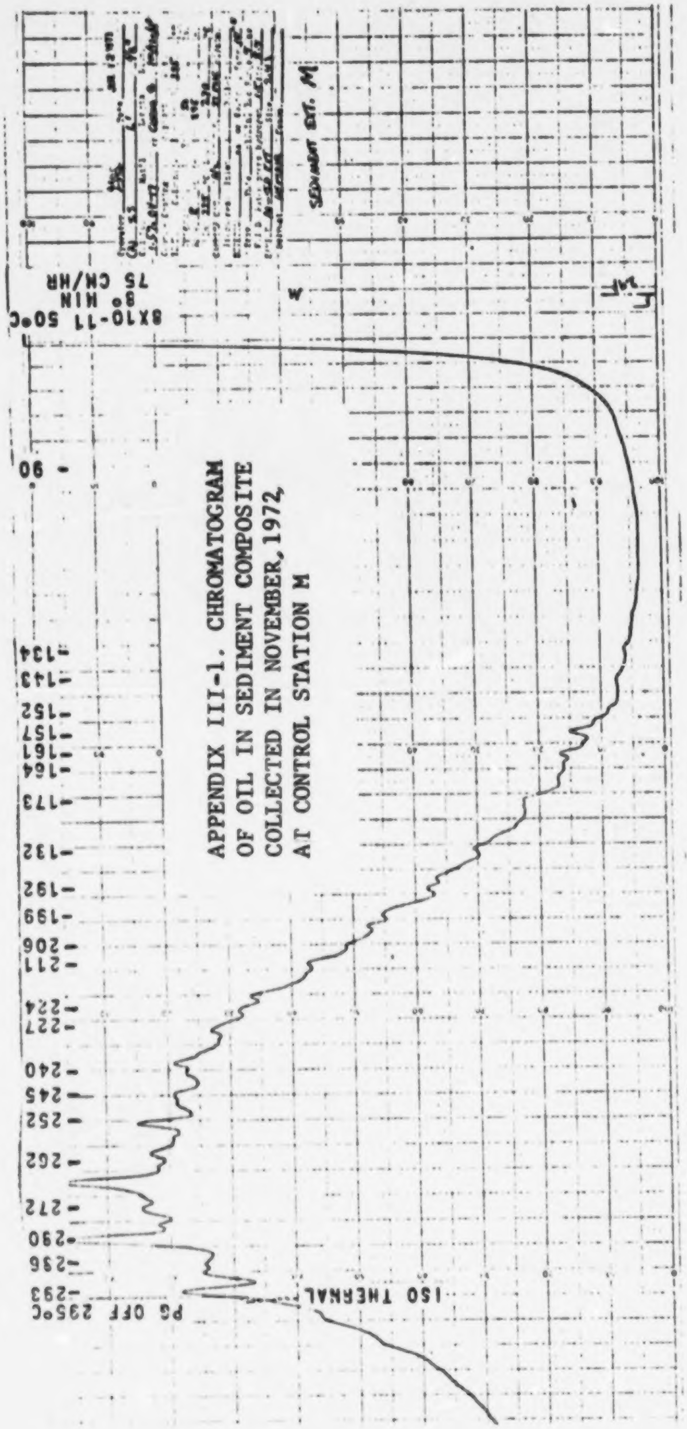
Appendix II-3. Concentrations of lead, zinc, cadmium, copper and mercury in Schuylkill River bottom sediments collected in November, 1972

	ppm Dry Weight[1]				
Sample Station	Lead	Zinc	Cadmium	Copper	Mercury
Monocacy*	500	930	3.9	290	0.013
Monocacy - 1	426	820	3.9	240	0.010
Monocacy - 2	445	640	2.8	277	0.021
Monocacy - 3	413	576	2.5	248	0.008
Monocacy - 4	435	602	2.2	242	0.016
Monocacy - 5	458	698	2.9	266	0.027
Douglassville - 1*	530	920	3.9	260	0.009
Douglassville - 2*	450	920	1.8	140	0.295
Douglassville - 3*	1400	650	3.1	190	0.016
Douglassville - 4*	690	700	2.6	240	0.115
Douglassville - 5*	780	510	2.3	190	0.045
Parker Ford - 1*	550	840	6.3	240	0.081
Parker Ford - 2*	460	1200	8.0	310	0.090
Parker Ford - 3*	70	130	0.2	51	0.130
Parker Ford - 4*	570	940	8.2	350	0.087
Parker Ford - 5*	690	1420	9.3	370	0.490

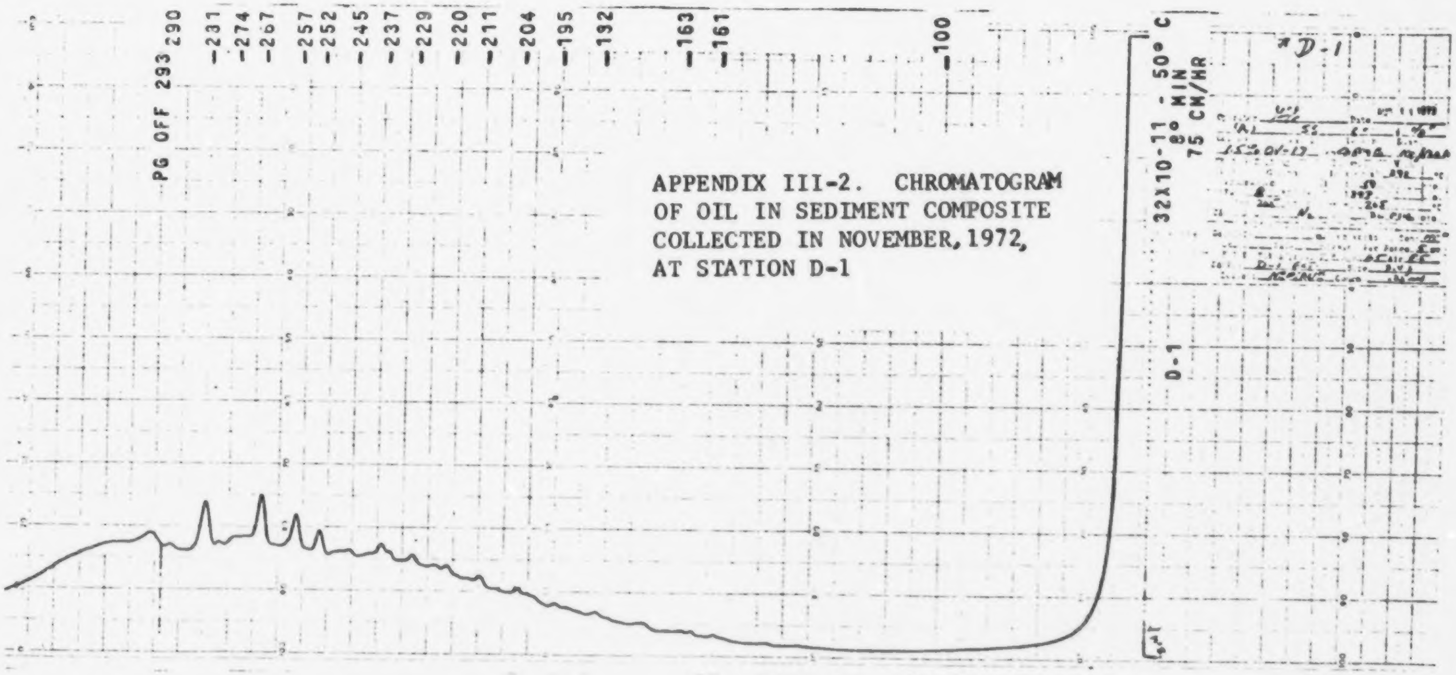
* Composite

[1] Mean of replicate analyses

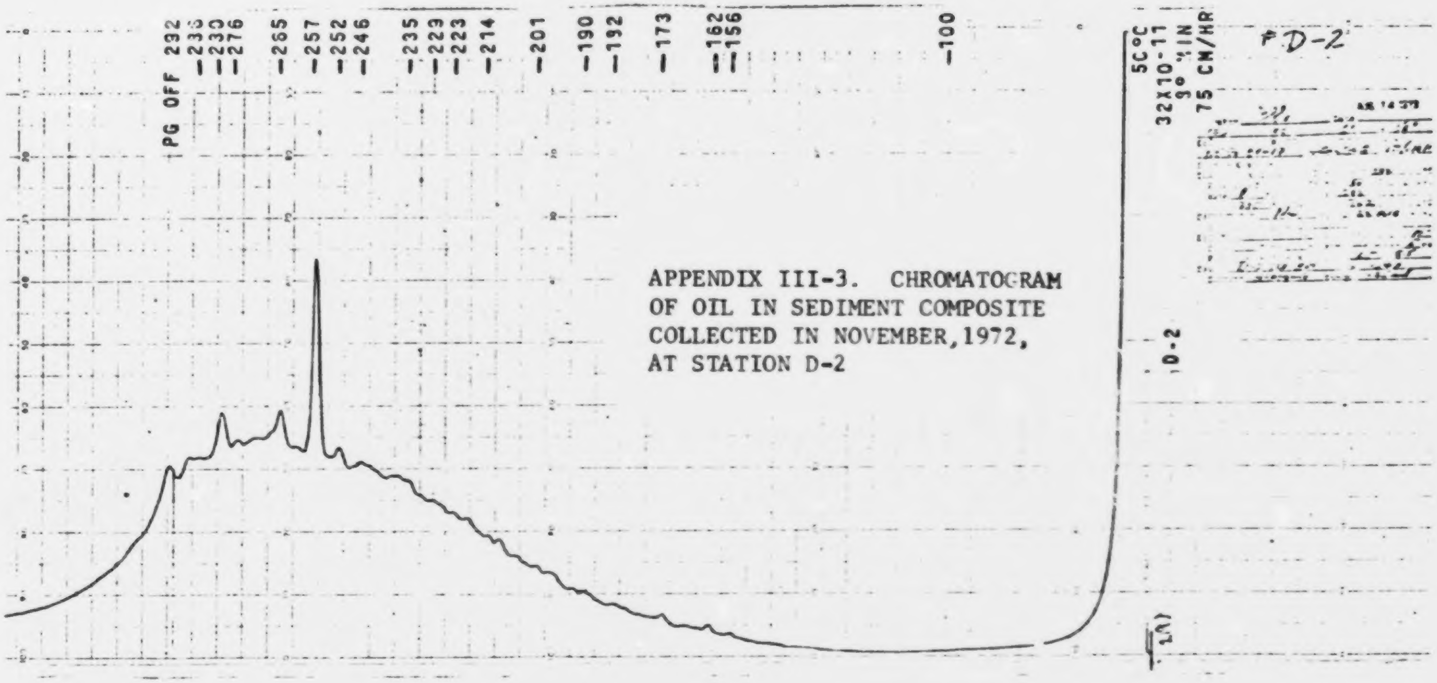
APPENDIX III DATA FROM HYDROCARBON ANALYSES OF SEDIMENTS



APPENDIX III-1. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT CONTROL STATION M



APPENDIX III-2. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION D-1



APPENDIX III-3. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION D-2

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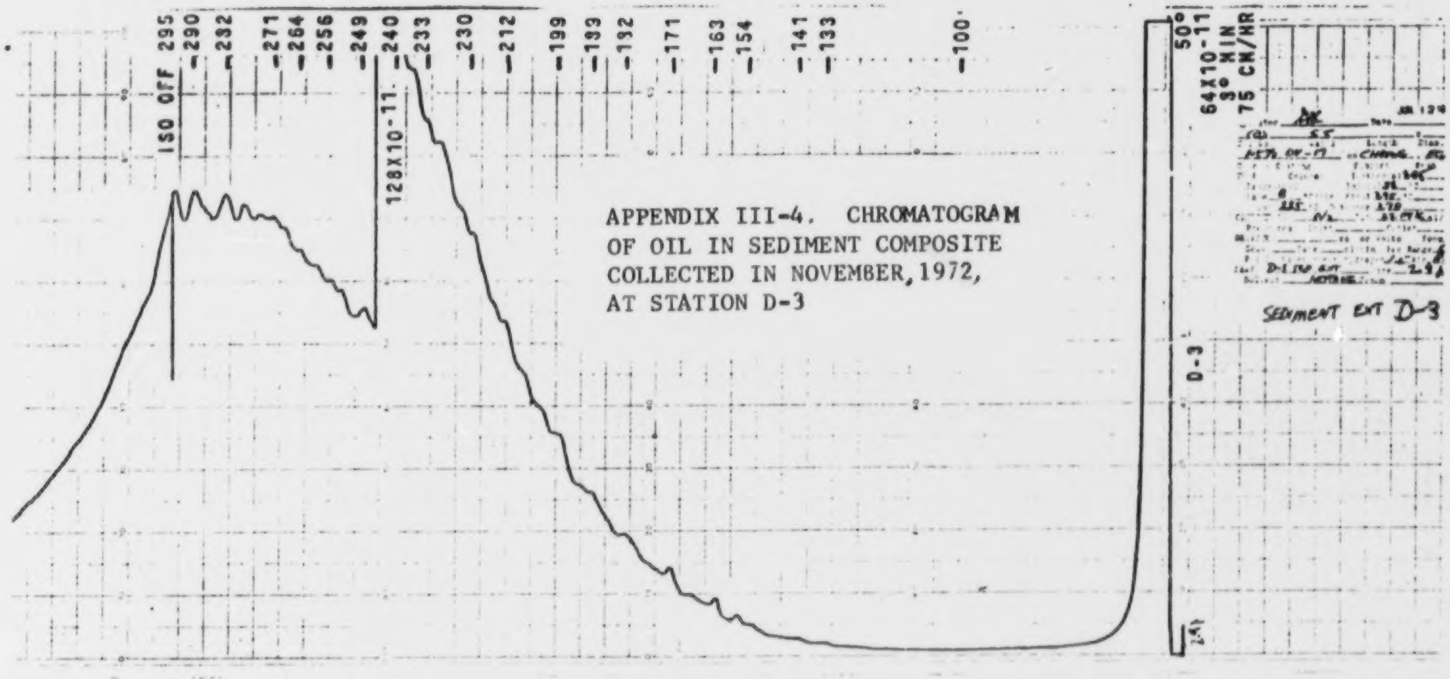
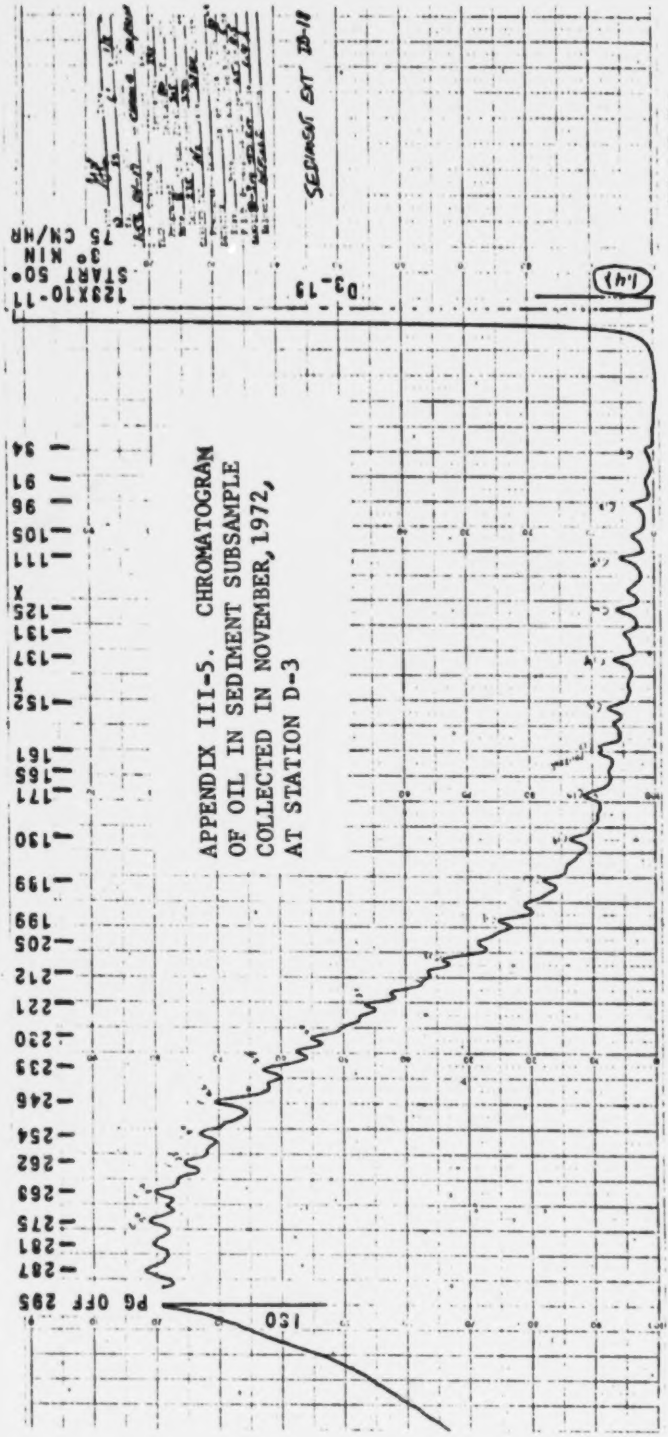
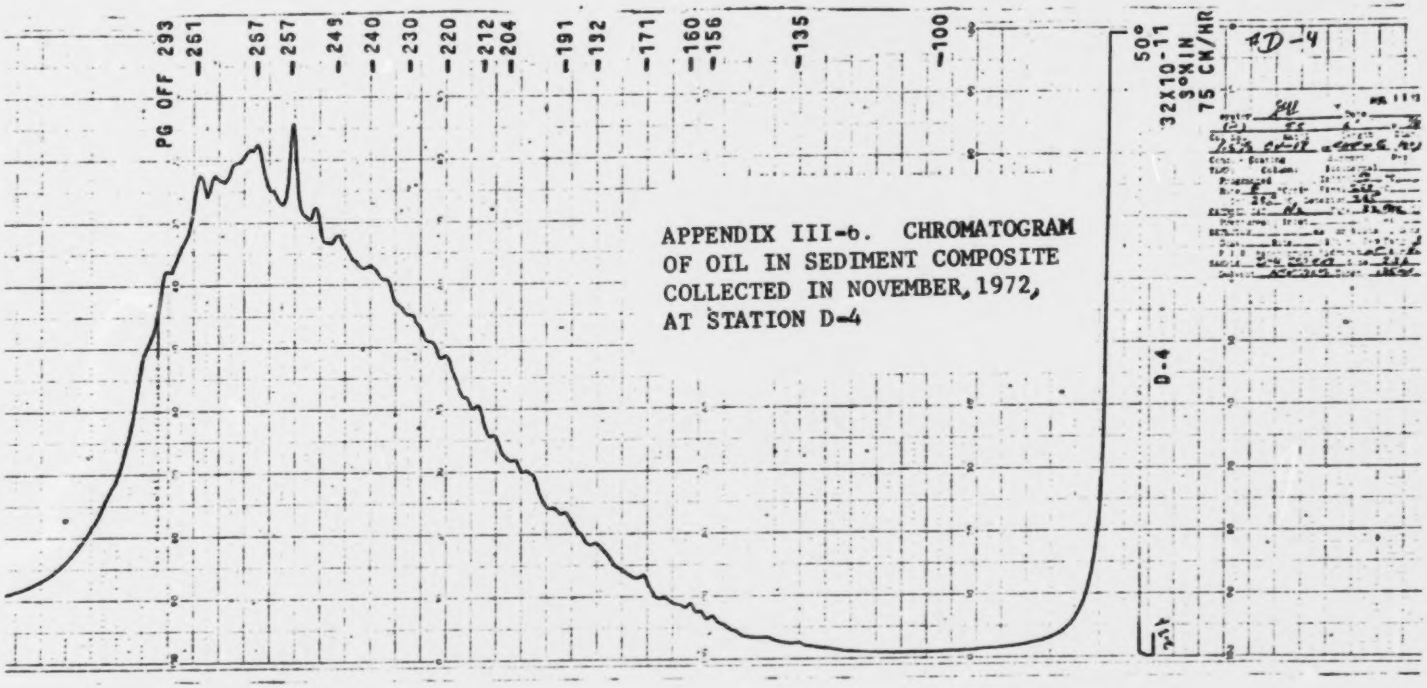


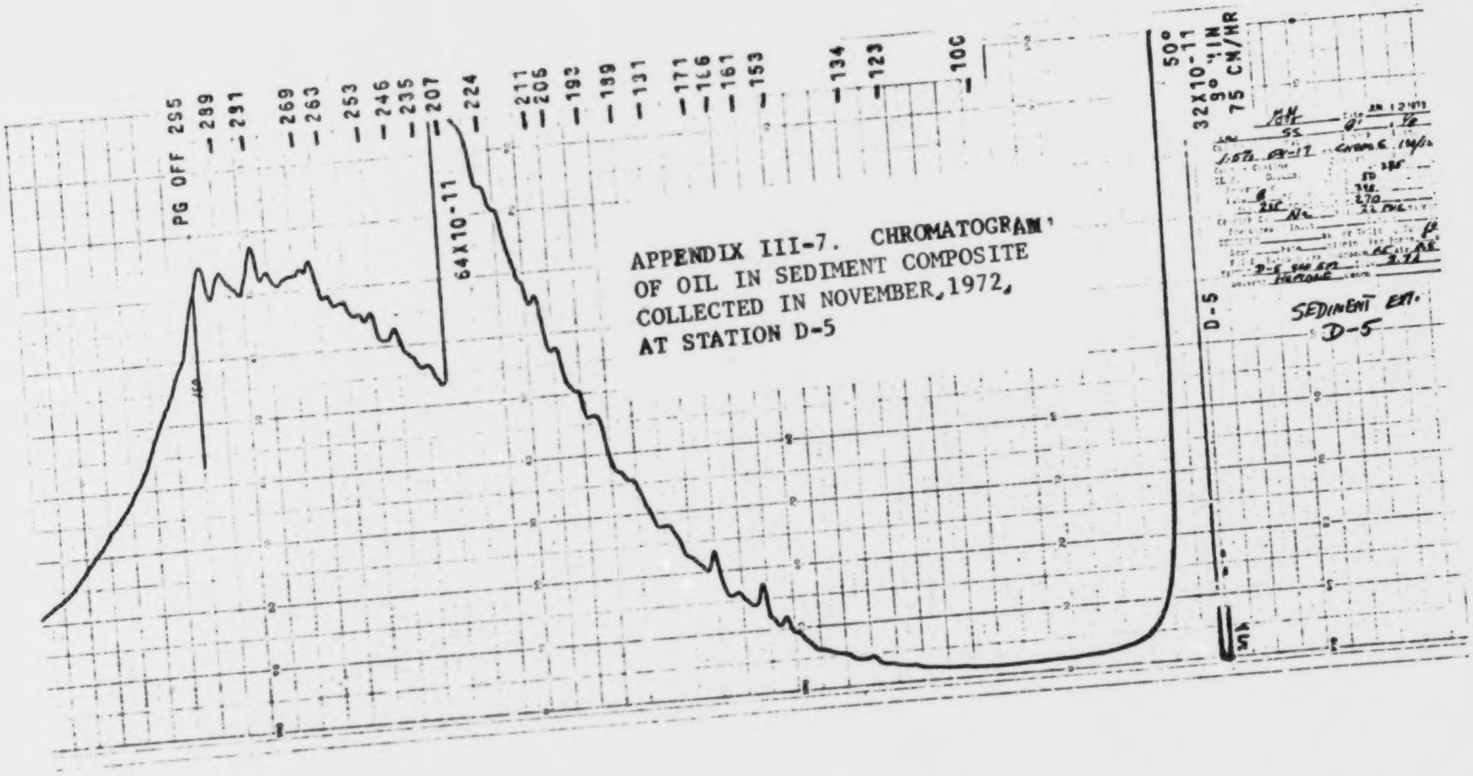
APPENDIX III-4. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION D-3



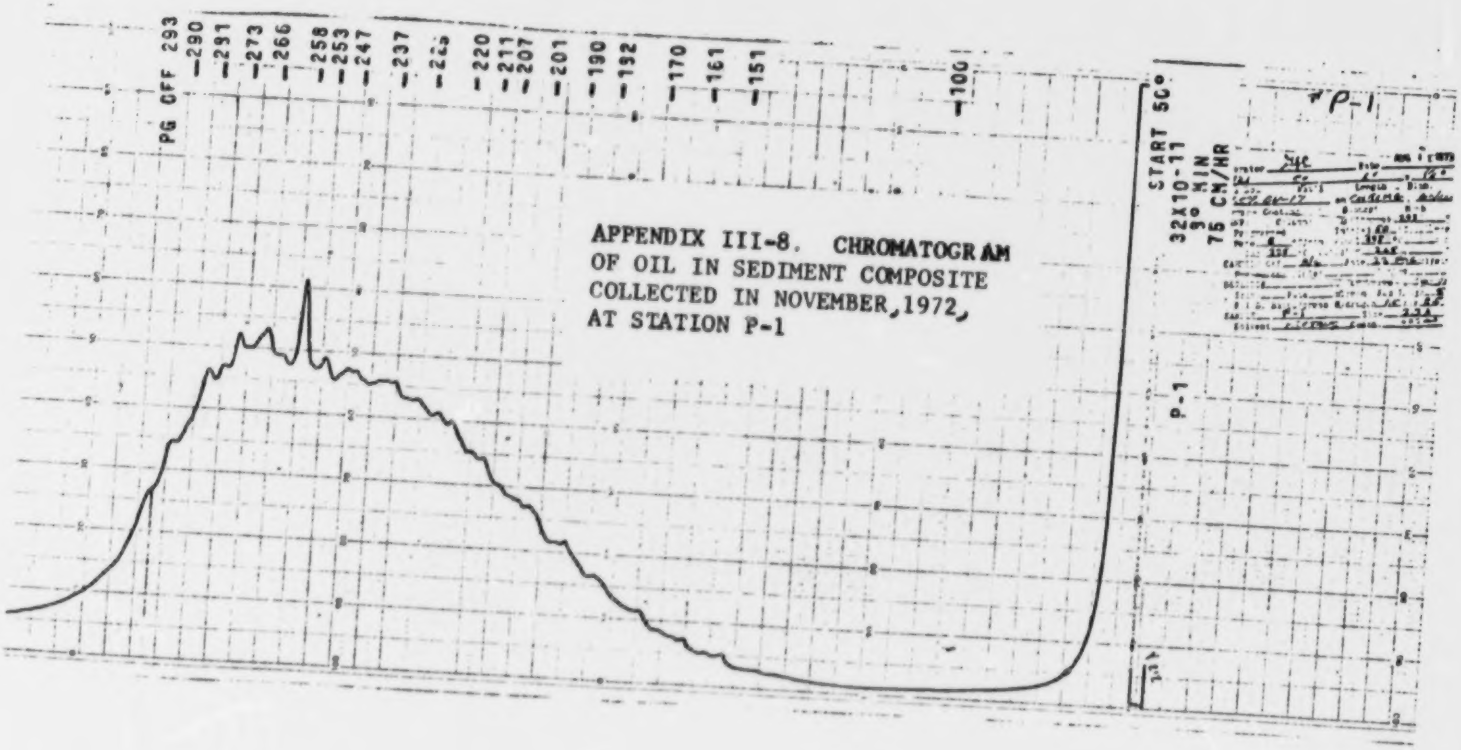
APPENDIX III-5. CHROMATOGRAM OF OIL IN SEDIMENT SUBSAMPLE COLLECTED IN NOVEMBER, 1972, AT STATION D-3



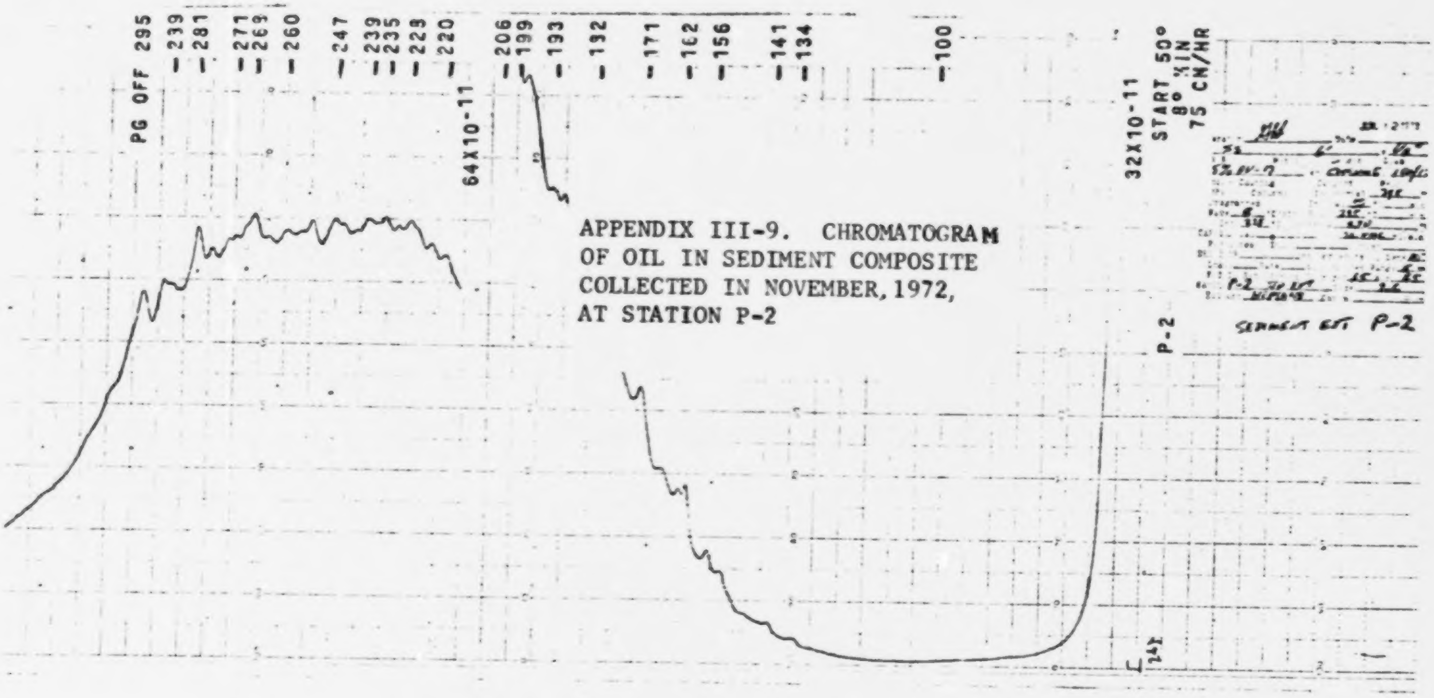
APPENDIX III-6. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION D-4



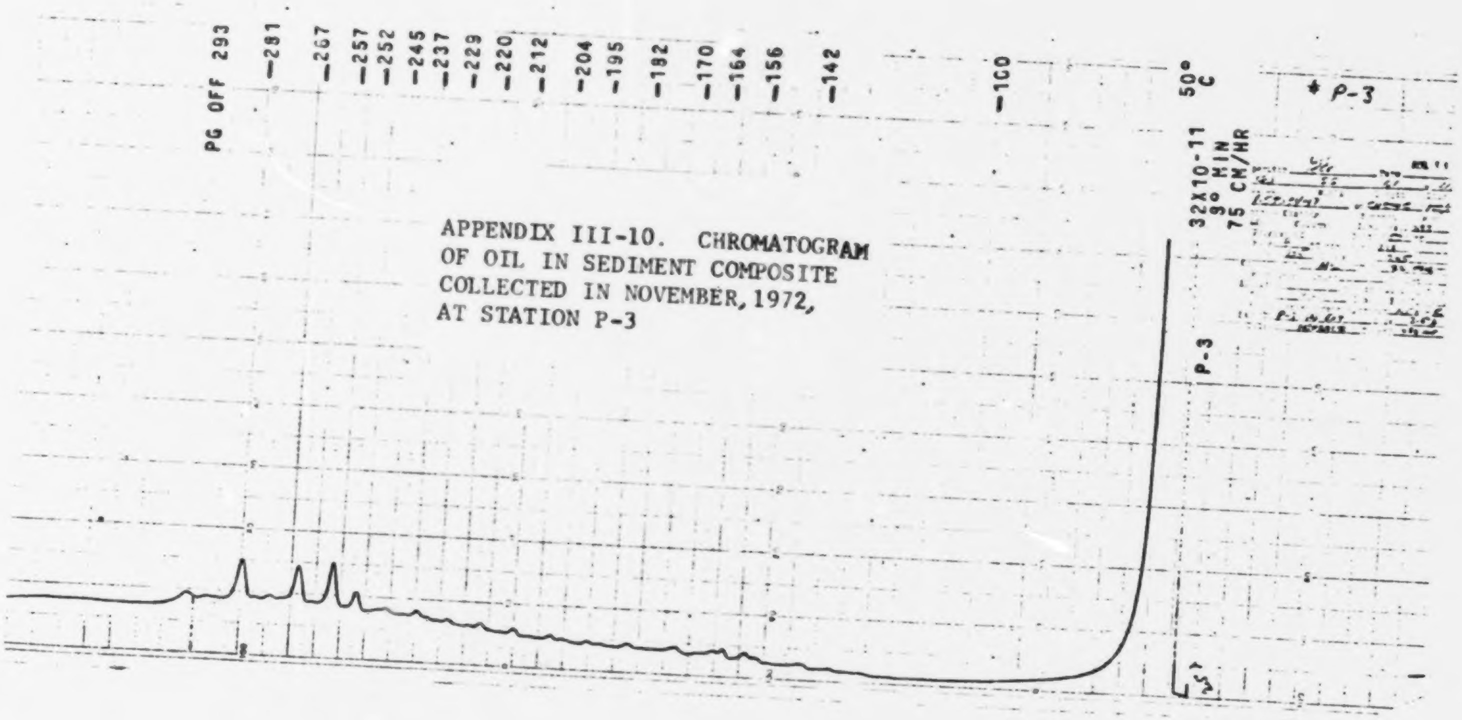
APPENDIX III-7. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION D-5



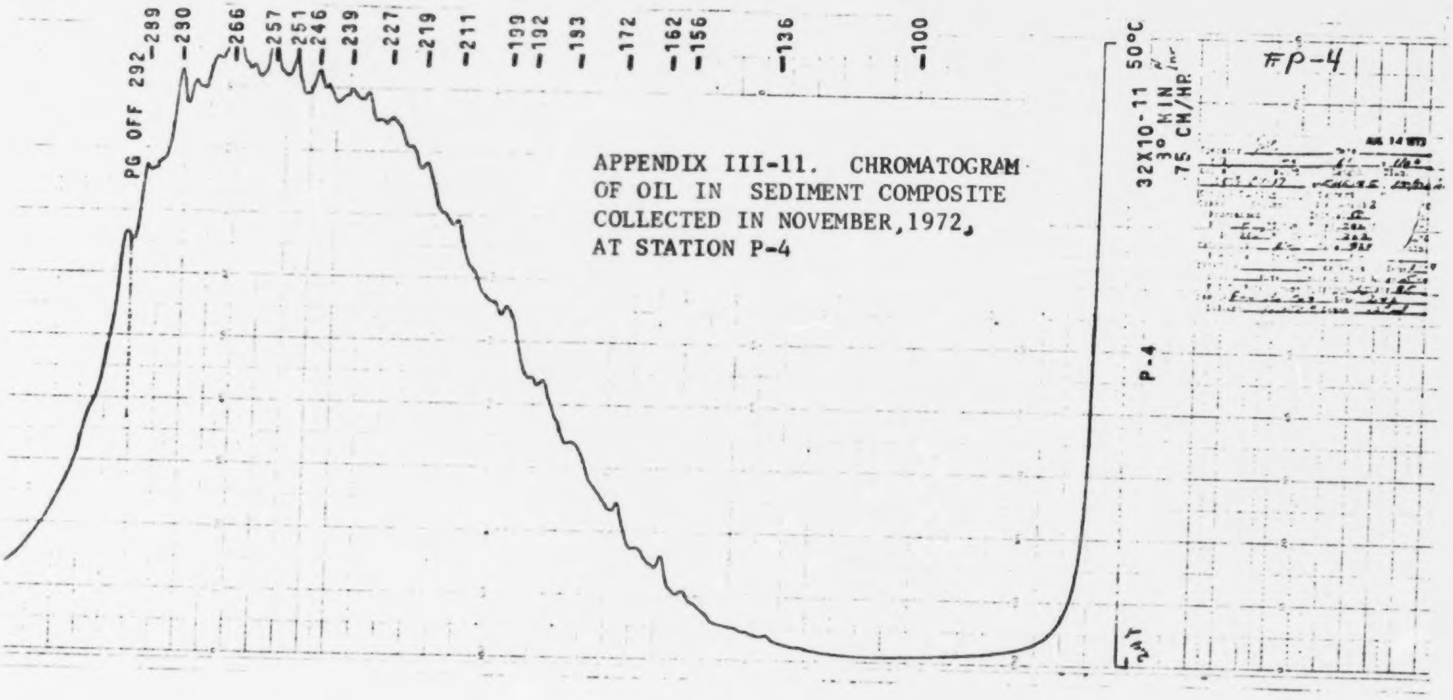
APPENDIX III-8. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION P-1



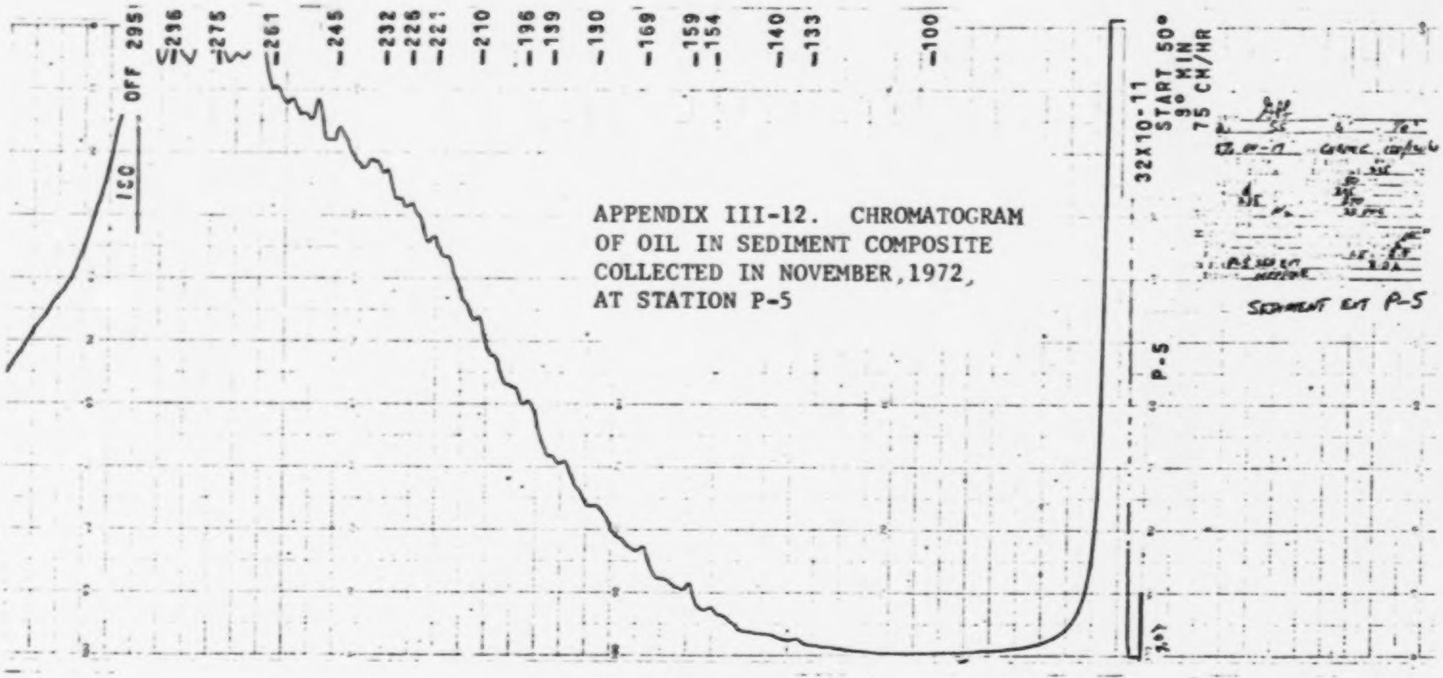
APPENDIX III-9. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION P-2



APPENDIX III-10. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION P-3



APPENDIX III-11. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION P-4



APPENDIX III-12. CHROMATOGRAM OF OIL IN SEDIMENT COMPOSITE COLLECTED IN NOVEMBER, 1972, AT STATION P-5

APPENDIX IV DATA FROM HEAVY METALS ANALYSES OF RIVER BIOTA

Appendix IV-1. Concentrations of lead, zinc, cadmium, and copper in benthic macrofauna collected in July, 1973

Sample	ppm (whole body, wet weight)				
	Lead	Zinc	Cadmium	Copper	Mercury
M(a)	49.3	102.0	0.1	29.7	*
M(b)	51.1	107.0	0.1	31.5	*
M(c)	51.4	99.5	0.1	35.0	*
M(d)	79.1	99.4	0.1	73.9	*
M(e)	10.9	43.3	0.1	71.1	*
M(f)	49.3	68.7	0.1	21.8	*
D2(a)	143.0	65.4	0.1	19.9	*
D2(b)	362.0	68.9	0.1	9.1	*
D2(c)	16.9	31.0	0.1	19.8	*
D3	24.2	38.6	0.1	7.0	*
D3	49.8	33.1	0.1	23.2	*

*Not abundant enough for mercury analysis.

Appendix IV-2. Concentrations of lead, zinc, cadmium, copper, and mercury in white suckers collected in November, 1972, January and July, 1973

Sample	Organ	ppm (wet weight)				
Monocacy		Lead	Zinc	Cadmium	Copper	Mercury
Nov. 1972						
Fish 1	Liver	<0.4	21.8	0.5	3.24	---
Fish 2	Liver	<0.4	21.3	0.2	3.83	---
July 1973						
Fish 1	Flesh	<0.4	4.0	<0.1	0.05	0.18
Fish 2	Flesh	<0.4	3.2	<0.1	0.05	0.14
Parkerford						
Jan. 1973						
Fish 1	Flesh	<0.4	15.9	0.1	0.60	0.12
Fish 2	Flesh	<0.4	20.5	<0.1	0.33	0.09
July 1973						
Fish 1	Flesh	0.7	5.4	<0.1	0.10	0.13
Fish 2	Flesh	0.5	4.6	<0.1	0.13	0.16

Appendix IV-3. Concentrations of lead, zinc, cadmium, copper, and mercury in brown bullheads collected in November, 1972, January and July, 1973

Sample	Organ	ppm (wet weight)				
Monocacy		Lead	Zinc	Cadmium	Copper	Mercury
Nov. 1972						
Fish 1	Liver	0.4	21.7	0.7	6.3	---
Fish 2	Liver	0.4	22.0	0.1	45.9	---
July 1973						
Fish 1	Flesh	0.4	2.1	0.1	0.05	0.18
Fish 2	Flesh	0.7	2.5	0.1	0.20	0.19
Fish 1	Liver	0.4	22.0	0.5	0.05	---
Parkerford						
Jan. 1973						
Fish 1	Liver	0.4	23.9	4.1	12.6	---
Fish 2	Liver	0.4	21.9	0.2	87.3	---
July 1973						
Fish 1	Flesh	0.4	2.7	0.1	0.05	0.07
Fish 2	Flesh	0.4	3.2	0.1	0.11	0.05
Fish 1	Liver	64.2	31.0	1.3	53	---
Fish 2	Liver	1.4	20.0	0.5	0.05	---

Appendix IV-4. Concentrations of lead, zinc, cadmium, copper, and mercury in crappies collected in November, 1972, and July, 1973

Sample	Organ	ppm (wet weight)				
Monocacy		Lead	Zinc	Cadmium	Copper	Mercury
Nov. 1972						
Fish 1	Liver	0.4	17.4	0.1	9.48	---
Fish 2	Liver	0.4	17.1	0.1	1.84	---
July 1973						
Fish 1	Flesh	0.4	3.8	0.1	0.05	0.09
Fish 2	Flesh	0.4	4.1	0.1	0.05	0.11
Parkerford						
July 1973						
Fish 1	Flesh	0.4	3.0	0.1	0.05	0.11
Fish 2	Flesh	0.4	11.1	0.1	0.05	0.08

Appendix IV-5. Concentrations of lead, zinc, cadmium, copper, and mercury in bluegills collected in November, 1972, and January, 1973

Sample	Organ	ppm (wet weight)				
Monocacy		Lead	Zinc	Cadmium	Copper	Mercury
Nov. 1972						
Fish 1	Flesh	0.4	10.4	0.1	1.79	0.10
Fish 2	Flesh	0.4	15.6	0.4	7.65	0.07
Parkerford						
Jan. 1973						
Fish 1	Liver	0.4	15.8	0.4	0.77	---
Fish 2	Liver	0.4	19.4	0.4	1.35	---

Appendix IV-6. Concentrations of lead, zinc, cadmium, and copper in Schuylkill River fishes collected 19 and 22 July, 1972

	Sample	Organ	Metal Concentration ppm			
			Lead	Zinc	Cadmium	Copper
Monocacy 19 & 22 July	Brown bullhead	Flesh	1.3	1.0	0.1	0.5
	Brown bullhead	Flesh	2.0	1.0	0.1	0.3
	Bluegill	Flesh	2.3	3.0	0.1	0.4
	Shiner	Flesh	2.6	7.9	0.1	0.4
Parkerford 19 & 22 July	Bluegill Composite 3 Samples 8.0, 7.2, 7.8 cm	Flesh	4.4	3.4	0.1	0.6

Appendix IV-7. Concentrations of lead, zinc, cadmium, and mercury in Schuylkill River fishes collected 23 and 29 July, 1972

	Sample	Organ	Metal Concentration ppm			
			Lead	Cadmium	Copper	Mercury
Monocacy 23 & 29 July	Bluegill	Flesh	0.9	0.38	0.5	0.741
	Brown bullhead	Flesh	0.3	0.10	0.2	0.776
	Brown bullhead (Composite)	Flesh	0.2	0.07	---	0.162
Parkerford 23 & 29 July	Bluegill	Flesh	0.5	0.06	0.6	0.330
	Bluegill (Comp.)	Flesh	1.0	0.10	---	0.104
	Bluegill (Comp.)	Flesh	1.0	0.08	0.1	0.241

APPENDIX V HYDROCARBON IN FISHES

Appendix V-1. Extraction Data

Sample description	Sample/ $MgSO_4$ extracted (g)	Wt. sample extracted (g)	Extraction time (hr)	Wt. oil product (g)	% Oil (based on sample*)
Spilled Crankcase Oil Waste (SCOW)	263	93	48	39.5	42.6
White suckers (downstream)	201	110	24	3.37	3.06
White suckers (upstream)	206	113	24	6.65	5.88
Brown bullheads (downstream)	200	116	24	3.21	2.77
Brown bullheads (upstream)	201	112	24	5.32	4.75
Crappies (downstream)	201	115	24	4.68	4.07
Crappies (upstream)	200	116	24	5.44	4.61

* Original fish or SCOW

Appendix V-2 Saponification Data

	Oil from extraction (g)	6N KOH (ml)	H_2O added (ml)	Solvent (ml)*	Oil product (g)	% oil prod.**
Spilled Crankcase Oil Waste (SCOW)	1.20	30	30	30	0.94	78.4
White suckers (downstream)	3.37	84	168	68	1.38	41.0
White suckers (upstream)	6.65	166	398	142	3.11	46.8
Brown bullheads (downstream)	3.21	80	160	64	0.57	17.8
Brown bullheads (upstream)	5.32	133	266	106	3.27	61.6
Crappies (downstream)	4.68	117	234	94	1.70	36.3
Crappies (upstream)	5.44	136	272	108	3.50	64.3

* Volume used in separatory funnel extraction, 2X with cyclohexane followed by 2X with benzene.

** Based on oil sample from first column

Appendix V-3. Column Chromatographic Data

(Cyclohexane Elutions)

	Spilled Crankcase Oil Waste	White suckers (downstream)	White suckers (upstream)	Brown bullheads (downstream)
Sample (g)	0.94	1.38	3.11	0.57
Alumina (g)	47	124	124	23
$MgSO_4$ (g)	4.7	12.4	12.4	2.3
Column diameter (cm)	2.0	5.0	5.0	2.0
Volume cyclohexane solvent (ml)	450	550	550	300
Aliphatic hydrocarbons (mg)	575	25	24	15
Aliphatic hydrocarbons (% based on above sample)	61	1.8	0.8	2.6

Appendix V-3 (Cont.) Column Chromatographic Data

(Cyclohexane Elutions)

	Brown bullheads (upstream)	Crappies (downstream)	Crappies (upstream)
Sample (g)	3.27	1.70	3.50
Alumina (g)	66	116	116
$MgSO_4$ (g)	6.6	11.6	11.6
Column diameter (cm)	2.0	5.0	5.0
Volume cyclohexane solvent (ml)	——*	600	600
Aliphatic hydrocarbons (mg)	——*	8	307**
Aliphatic hydrocarbons (% based on above sample)	——*	.5	8.8**

* Column clogged with gel, analysis abandoned

** Solid gel eluted

Appendix V-3 (Cont.) Column Chromatographic Data

(Benzene-Benzene/Ether Elutions)

	Spilled Crankcase Oil Waste	White suckers (downstream)	White suckers (upstream)	Brown bullheads (downstream)
Sample (g)	0.94	1.38	3.11	0.57
Alumina (g)	47	124	124	23
$MgSO_4$ (g)	4.7	12.4	12.4	2.3
Column diameter (cm)	2.0	5.0	5.0	2.0
Volume benzene solvent (ml	200	400	250	300
Volume benzene/ ether* solvent (ml)	200	150	150	200
Aromatic hydrocarbons (mg)**	107	15	15	9
Aromatic hydrocarbons (% based on above sample)	11.4	1.1	.5	1.6

* 90/10 v/v benzene/ether

** From combining benzene-benzene/ether fractions

Appendix V-3 (Cont.) Column Chromatographic Data

(Benzene-Benzene/Ether Elutions)

	Brown bullheads (upstream)	Crappies (downstream)	Crappies (upstream)
Sample (g)	3.27	1.70	3.50
Alumina (g)	66	116	116
$MgSO_4$ (g)	6.6	11.6	11.6
Column diameter (cm)	2.0	5.0	5.0
Volume benzene solvent (ml)	——***	350	500
Volume benzene/ ether* solvent (ml)	——***	150	200
Aromatic hydrocarbons (mg)**	——***	10	214+
Aromatic hydrocarbons (% based on above sample)	——***	0.6	6.1

* 90/10 v/v benzene/ether

** From combining benzene-benzene/ether fractions

*** Column clogged with gel during cyclohexane elutions

+ Solid gel eluted

Appendix V-4. Extraction and Saponification Results From Harrison Lake National Fish Hatchery Fish

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	HLFH* fish extracted (g)	ppm added hydrocarbon	Percent oil from extraction based on (1)**	Oil saponified (g)	Oil obtained from saponification (g)	Percent oil from saponification based on (4)
HLFH-1	246	0	5.3	4.89	.44	8.9
HLFH-2	254	2	7.2	8.00	.38	4.7
HLFH-3	226	5	5.9	8.00	.44	5.6
HLFH-4	80	10	4.9	3.96	.29	7.2

* HLFH: Harrison Lake National Fish Hatchery

** Extractions conducted on fish/$MgSO_4$ mixtures 44-48 hrs. in refluxing benzene

Appendix V-5. Column Chromatographic Data Harrison Lake National Fish Hatchery (HLFH) Fish

Sample	Oil from saponification for chromatography (g)	Added Hydrocarbon (ppm)	Non-volatile residue from cyclohexane elution (mg)*	Non-volatile residue from benzene elution (mg)**	Residue from cyclohexane elution (ppm)	Residue from benzene elution (ppm)
HLFH-1	.44	0	1	3	11	33
HLFH-2	.38	2	2	4	13	40
HLFH-3	.44	5	2	6	12	45
HLFH-4	.29	10	1	5	17	66

* Column eluted with cyclohexane (425 ml)

** Column eluted with 650 ml benzene + 350 ml 90/10 benzene/ethyl ether (v/v)

Appendix V-6 Peak Area and Weight Correlations of Polycyclic Aromatic Hydrocarbons Compared to Triphenylmethane Internal Standard

Chromatograph sample: 1) 10.0 ml standard hydrocarbon (HC) mixture (1.16 mg each hydrocarbon)+
2) 1.50 ml (1.63 mg) triphenylmethane (TPM) in benzene

Chromatogram: Fig. 55

Peak number	Aromatic hydrocarbon	Peak area** X10^{-2} (mm^{-2})	Area HC÷ area TPM	Wt HC÷ wt TPM	Area ratio HC/TPM÷ wt ratio HC/TPM***
1	Phenathrene	3.3	.72	.71	1.0
2	Fluoranthene	3.4	.74	.71	1.0
3	Pyrene	3.3	.72	.71	[illegible]
4	Chrysene/1,2 benzanthracene	6.3	1.4	1.4	1.0
5	Benzo (a) pyrene	3.0	.65	.71	.92
6	Benzo (ghi) perylene	2.5	.54	.71	.76
TPM	TPM	4.6			

** Height (mm) x width at 1/2 peak height (mm)

*** Values used as correction factors in Appendix V-7, -8, -9

Appendix V-7. Percent Recovery of Polycyclic Aromatic Hydrocarbons from Harrison Lake National Fish Hatchery Fish (2 ppm Added Hydrocarbon)

Chromatograph sample: 1) Benzene eluate from column chromatography (4.4 mg. solids) +
2) 0.70 ml. benzene solvent +
3) 0.30 ml.(0.33 mg) triphenylmethane (TPM) in benzene

Chromatogram: Fig. 58

Hydrocarbon (HC)	Area HC ÷ area TPM	Corr.* factor	Wt. HC ÷ wt. TPM	HC (mg)	Theor** HC (mg)	Percent HC recovery
Phenanthrene	.18	1.0	.18	.059	.22	27
Fluoranthene	.31	1.0	.31	.10	.22	45
Pyrene	.28	1.0	.28	.092	.22	42
Chrysene/1,2 benzanthracene	.59	1.0	.59	.19	.44	43
Benzo (a) pyrene	.21	.92	.23	.075	.22	34
Benzo (ghi) perylene	.26	.76	.34	.11	.22	50

* See last column, Appendix V-6

** Based on known quantities (2 ppm) of each added hydrocarbon to ground fish before blending, and subsequently processed (extraction - saponification - column chromatography)

Appendix V-8. Percent Recovery of Polycyclic Aromatic Hydrocarbons from Harrison Lake National Fish Hatchery Fish (5 ppm Added Hydrocarbon)

Chromatograph sample: 1) Benzene eluate from column chromatography (6.1 mg solids) +
2) 1.00 ml benzene solvent +
3) 0.80 ml (0.87 mg) triphenylmethane (TPM) in benzene

Chromatogram: Fig. 59

Hydrocarbon (HC)	Area HC ÷ area TPM	Corr* factor	Wt HC ÷ wt TPM	HC (mg)	Theor** wt HC (mg)	Percent HC recovery
Phenanthrene	.42	1.0	.42	.37	.68	54
Fluoranthene	.60	1.0	.60	.52	.68	76
Pyrene	.58	1.0	.58	.50	.68	74
Chrysene/1,2 benzanthracene	1.0	1.0	1.0	.87	1.4	62
Benzo (a) pyrene	.42	.92	.46	.40	.68	59
Benzo (ghi) perylene	.63	.76	.83	.72	.68	106

* See last column, Appendix V-6

** Based on known quantities (5 ppm) of each added hydrocarbon to ground fish before blending, and subsequently processed (extraction - saponification - column chromatography)

Appendix V-9. Percent Recovery of Polycyclic Aromatic Hydrocarbons from Harrison Lake National Fish Hatchery Fish (10 ppm Added Hydrocarbon)

Chromatograph sample:
1) Benzene eluate from column chromatography (5.3 mg solids) +
2) 0.90 ml benzene solvent +
3) 0.60 ml (0.65 mg) triphenylmethane (TPM) in benzene

Chromatogram: Fig. 60

Hydrocarbon (HC)	Area HC ÷ area TPM	Corr* factor	Wt HC ÷ wt TPM	Wt HC (mg)	Theor** wt HC (mg)	Percent HC recovery
Phenanthrene	.65	1.0	.65	.42	.80	53
Fluoranthene	.86	1.0	.86	.56	.80	70
Pyrene	.89	1.0	.89	.58	.80	73
Chrysene/1,2 benzanthracene	1.5	1.0	1.5	.98	1.6	61
Benzo (a) pyrene	.49	.92	.53	.34	.80	43
Benzo (ghi) perylene	.73	.76	.96	.62	.80	78

* See last column, Appendix V-6.

** Based on known quantities (10 ppm) of each added hydrocarbon to ground fish before blending, and subsequently processed (extraction - saponification - column chromatography)

APPENDIX VI DATA FROM BIOLOGICAL ANALYSES

Appendix VI-1. Chlorophyll-a content of Schuylkill River water above and below the oil spill site in July, 1972

		Chlorophyll A (micrograms/liter)		
Date	Station[1]	Total	Active	Pheopigment (Dead)
16 July 1972				
	ABOVE SPILL			
	Monocacy Bridge	3.78	2.78	1.00
		3.41	2.63	0.78
	Average	3.60	2.71	0.89
	BELOW SPILL			
	Parker Ford Bridge	8.48	6.72	1.76
		11.70	4.39	7.31
	Average	10.09	5.56	4.54
	Valley Forge Bridge	7.66	6.27	1.39
		14.19	11.39	2.80
	Average	10.93	8.83	2.10
29 July 1972				
	ABOVE SPILL			
	Monocacy Bridge	6.15	4.80	1.35
		--	--	--
	Average	6.15	4.80	1.35
	BELOW SPILL			
	Parker Ford Bridge	10.46	8.13	2.33
		10.46	7.73	2.73
	Average	10.46	7.93	2.53

Appendix VI-1. (continued)

Date	Station[1]	Chlorophyll A (micrograms/liter) Total	Active	Pheopigment (Dead)
29 July 1972				
	BELOW SPILL			
	Valley Forge Bridge	14.19	10.58	3.61
		11.45	9.24	2.21
	Average	12.82	9.91	2.41

---

[1] Duplicate samples were usually taken at each station.

Appendix VI-2. Zooplankton abundance in Schuylkill River water above and below the oil spill in July, November, and December, 1972, and July, 1973

	16 July 1972			29 July 1972		
	Above Spill	Below Spill		Above Spill	Below Spill	
STATION:	Monocacy	Parker Ford	Valley Forge	Monocacy	Parker Ford	Valley Forge
Taxons						
Peritricha	--				100+	100+
Protozoa	--		100+			
Coelenterata	--					18
Nemertina (ribbon worms)	4					
Rotifera	--			3		12
Nematoda (round worms)		1		3		3
Nematomorpha (hair worms)						
Bryzoa (moss animals)			100+		100+	100+
Pelecypoda (bivalve mollusk) larvae	2					

Appendix VI-2. (continued)

	16 July 1972			29 July 1972		
	Above Spill	Below Spill		Above Spill	Below Spill	
STATION:	Monocacy	Parker Ford	Valley Forge	Monocacy	Parker Ford	Valley Forge
Taxons						
Oligochaeta (segmented worms)			2	13	30	6
Tardigrada (water bears)						
Cladocera (water fleas)	61	92	80	3		24
Ostracoda	9			5		
Copepoda	13	41	48	10	5	21
Amphipoda	1					
Hydracarina (water mites)	9	6				
Hemiptera (true bugs)	1					
Odonata (dragon and damsel fly) larvae		1			100+	
Trichoptera (caddis fly) larvae	1	3	5			

Appendix VI-2. (continued)

	16 July 1972			29 July 1972		
	Above Spill	Below Spill		Above Spill	Below Spill	
STATION:	Monocacy Bridge	Parker Ford Bridge	Valley Forge Bridge	Monocacy Bridge	Parker Ford Bridge	Valley Forge Bridge
Taxons						
Ephemeroptera (May fly) larvae						
Tendipedidae (midge) larvae		4		68	149	95
Culicidae (mosquito) larvae				5		3
Coleoptera (beetles)	3			10		
Unidentified	8	15	1	5	5	12
Major taxon diversity	10	7	7	9	6	10

Appendix VI-2. (continued)

	28 November 1972		1 December 1972		14 July 1973	
	Above Spill	Below Spill	Above Spill	Below Spill	Above Spill	Below Spill
STATION:	Monocacy	Parker Ford[1]	Monocacy	Parker Ford	Monocacy	Parker Ford
Taxons						
Peritricha		2		3		1
Protozoa	1		2		4	4
Coelenterata	<1					
Nemertina (ribbon worms)	6	<1	7	<1	11	1
Rotifera	7	<1	11	<1		
Nematoda (round worms)		<1		<1		
Nematomorpha (hair worms)	<1		9			
Bryzoa (moss animals)	<1	<1	7	<1		

Appendix VI-2. (continued)

	28 November 1972		1 December 1972		14 July 1973	
	Above Spill	Below Spill	Above Spill	Below Spill	Above Spill	Below Spill
STATION:	Monocacy	Parker Ford[1]	Monocacy	Parker Ford	Monocacy	Parker Ford
Taxons						
Pelecypoda (bivalve mollusk) larvae				<1		
Oligochaeta (segmented worms)	2	4	13	1	4	3
Tardigrada (water bears)					2	
Cladocera (water fleas)	5	5	7	<1	7	5
Ostracoda						
Copepoda	1		9		4	
Amphipoda						
Hydracarina (water mites)						1
Hemiptera (true bugs)		<1			2	1

Appendix VI-2. (continued)

	28 November 1972		1 December 1972		14 July 1973	
	Above Spill	Below Spill	Above Spill	Below Spill	Above Spill	Below Spill
STATION:	Monocacy	Parker Ford[1]	Monocacy	Parker Ford	Monocacy	Parker Ford
Taxons						
Odonata (dragon and damsel fly) larvae						1
Trichoptera (caddis fly) larvae						
Ephemeroptera (May fly) larvae			9	< 1	83	46
Tendipedidae (midge) larvae						
Culicidae (mosquito) larvae						1
Coleoptera (beetles)						
Unidentified	—	—	—	—	—	—
Major taxon diversity	9	9	9	9	8	10

[1] Oil droplets were observed in this sample

Appendix VI-3. Benthic macrofauna abundance in Schuylkill River sediments in November, 1972, and July, 1973

STATION: Above Spill	Monocacy (Replicate 1)		Monocacy (Replicate 2)		Monocacy (Replicate 3)	
	Organisms/m^2	Type 1, 2	Organisms/m^2	Type	Organisms/m^2	Type
Taxons						
Nematoda (round worms)	86		43			
Gastropoda (snails)					43	(4)
Pelecypoda (bivalve mollusks)	86	(1)	43	(1)	43	(1)
Oligochaeta (segmented worms)	15,566	(1)+ (2)+ (5)	7,912	(1) (2)	5,461	(1)+(2)+(5)
Hirudinea (leeches)					43	(1)
Odonata (dragon-damsel fly) larvae						
Tendipedidae (midge) larvae and pupae	129				86	
Ceratopogonidae (biting midge) larvae and pupae						
Other Diptera larvae and pupae	215	(1)				
Fish larvae						
Major taxon diversity	5		3		5	

Appendix VI-3. (continued)

29 November 1972

STATION: Below Spill	Parker Ford 1		Parker Ford 2		Parker Ford 3	
Taxons	Organisms/m^2	Type	Organisms/m^2	Type	Organisms/m^2	Type
Nematoda (round worms)						
Gastropoda (snails)	301	(1)(2)(4)				
Pelecypoda (bivalve mollusks)	172	(1)				
Oligochaeta (segmented worms)	3, 314	(1)+(2)+ (3)(4)	No		11,621	(1)+(2)+ (4)(6)
Hirudinea (leeches)			Organisms			
Odonata (dragon-damsel fly) larvae						
Tendipedidae (midge) larvae and pupae	43				301	
Ceratopogonidae (biting midge) larvae and pupae					43	
Other Diptera larvae and pupae	43	(1)				
Fish larvae						
Major taxon diversity	5		0		3	

Appendix VI-3. (continued)

29 November 1972

STATION: Below Spill	Douglassville 1		Parker Ford 4		Parker Ford 5	
	Organisms/m^2	Type	Organisms/m^2	Type	Organisms/m^2	Type
Taxons						
Nematoda (round worms)			129		86	
Gastropoda (snails)			301	(1)+(3)(4)	43	(2)
Pelecypoda (bivalve mollusks)			43	(2)		
Oligochaeta (segmented worms)	43	(1)	29,123	(1)+(2)+ (3)(4)(5)	6,327	(1)+(4)
Hirudinea (leeches)						
Odonata (dragon-damsel fly) larvae					43	
Tendipedidae (midge) larvae and pupae			129		258	
Ceratopogonidae (biting midge) larvae and pupae			129			
Other Diptera larvae and pupae	43	(1)	301	(1)	86	(1)
Fish larvae						
Major taxon diversity	2		7		6	

Appendix VI-3. (continued)

29 November 1972

STATION: Below Spill	Douglassville 2		Douglassville 3		Douglassville 4	
Taxons	Organisms/m^2	Type	Organisms/m^2	Type	Organisms/m^2	Type
Nematoda (round worms)						
Gastropoda (snails)					43	(1)
Pelecypoda (bivalve mollusks)						
Oligochaeta (segmented worms)	12,986	(1)+(2)+(3)(4)	989	(1)+(2)+(3)(4)	1,851	(1)+(2)+(3)(4)
Hirudinea (leeches)	43					
Odonata (dragon-damsel fly) larvae						
Tendipedidae (midge) larvae and pupae					129	
Ceratopogonidae (biting midge) larvae and pupae						
Other Diptera larvae and pupae					43	(1)
Fish larvae					43	
Major taxon diversity	2		1		5	

Appendix VI-3. (continued)

29 November 1972

STATION: Below Spill Taxons	Douglassville 5 Organisms/m^2	Type
Nematoda (round worms)	43	
Gastropoda (snails)		
Pelecypoda (bivalve mollusks)		
Oligochaeta (segmented worms)	4,433	(1)+(2)+ (3)(4)
Hirudinea (leeches)	43	(1)
Odonata (dragon-damsel fly) larvae		
Tendipedidae (midge) larvae and pupae	129	
Ceratopogonidae (biting midge) larvae and pupae	43	
Other Diptera larvae and pupae		
Fish larvae		
Major taxon diversity	5	

Appendix VI-3. (continued)

28 July 1973

STATION: Above Spill	Monocacy (Replicate 1) Organisms/m^2	Type	Monocacy (Replicate 2) Organisms/m^2	Type	Monocacy (Replicate 3) Organisms/m^2	Type
Taxons						
Nematoda (round worms)			43			
Gastropoda (snails)						
Pelecypoda (bivalve mollusks)						
Oligochaeta (segmented worms)	688	(1)+(2)+ (3)	301	(1)+(2)+ (3)(6)	1,419	(1)+(2)+ (3)
Hirudinea (leeches)						
Odonata (dragon-damsel fly) larvae						
Tendipedidae (midge) larvae and pupae	1,290		4,601		1,643	
Ceratopogonidae (biting midge) larvae and pupae						
Other Diptera larvae and pupae						
Fish larvae						
Major taxon diversity	2		3		2	

Appendix VI-3. (continued)

28 July 1973

STATION: Above Spill	Monocacy (Replicate 4)		Monocacy (Replicate 5)	
	Organisms/m^2	Type	Organisms/m^2	Type
Taxons				
Nematoda (round worms)			86	
Gastropoda (snails)				
Pelecypoda (bivalve mollusks)				
Oligochaeta (segmented worms)	1,634	(1)+(2)+ (3)	2,838	(1)+(2)+ (3)
Hirudinea (leeches)				
Odonata (dragon-damsel fly) larvae				
Tendipedidae (midge) larvae and pupae	3,096		1,032	
Ceratopogonidae (biting midge) larvae and pupae				
Other Diptera larvae and pupae				
Fish larvae				
Major taxon diversity	2		2	

Appendix VI-3. (continued)

28 July 1973

STATION: Below Spill	Douglassville Br. (Replicate 1)		Douglassville Br. (Replicate 2)	
	Organisms/m^2	Type	Organisms/m^2	Type
Taxons				
Nematoda (round worms)			86	
Gastropoda (snails)				
Pelecypoda (bivalve mollusks)				
Oligochaeta (segmented worms)	5,246	(1)+(2)+ (3)(4)	2,666	(1)+(2)+ (3)
Hirudinea (leeches)				
Odonata (dragon-damsel fly) larvae				
Tendipedidae (midge) larvae and pupae	1,677		4,472	
Ceratopogonidae (biting midge) larvae and pupae				
Other Diptera larvae and pupae				
Fish larvae				
Major taxon diversity	2		3	

Appendix VI-3. (continued)

28 July 1973

STATION: Below Spill	Douglassville 2		Douglassville 4	
	Organisms/m^2	Type	Organisms/m^2	Type
Taxons				
Nematoda (round worms)				
Gastropoda (snails)				
Pelecypoda (bivalve mollusks)				
Oligochaeta (segmented worms)			7,482	(1)+(2), (3)+(4)
Hirudinea (leeches)				
Odonata (dragon-damsel fly) larvae				
Tendipedidae (midge) larvae and pupae	3,870		1,030	
Ceratopogonidae (biting midge) larvae and pupae			86	
Other Diptera larvae and pupae				
Fish larvae				
Major taxon diversity	1		3	

Appendix VI-3. (continued)

[1] Type of macrofauna present is described by the following codes:

Gastropoda: (1) *Ferissia*; (2) *Physa*; (3) *Lymnaea*; (4) *Gyranlus*(?)

Pelecypoda: (1) *Pisiclium*; (2) *Musculium*

Oligochaeta: (1) *Tubifex*; (2) *Limnodriluso*; (3) *Peloscolex*;
(4) *Nais*; (5) Lumbriculidae; (6) Enchytraeidae

Hirudinea: (1) Glossiphoniidae

Other Diptera larvae and pupae: (1) Psychodidae

[2] Abundance within taxons is indicated by "+" signs.

Appendix VI-4. Counts of bacteria in Schuylkill River sediment (organisms/g of sediment) above and below oil spill in July, 1972

STATION:	Hydrocarbon Oxidizers	Casein Splitters	Starch Splitters	Glucose Fermenters (MPN)	Sulfate Fermenters (MPN)
			17 July 1972		
ABOVE SPILL					
Monocacy	No results.	4.5×10^6	6.8×10^6	2.4×10^5	1.5×10^2
BELOW SPILL	Agar was				
Parker Ford Br.	contaminated.	1.0×10^7	4.2×10^7	4.6×10^6	2.4×10^3
Valley Forge Br.		3.9×10^6	1.3×10^6	9.6×10^5	3.0×10^1
			23 July 1972		
ABOVE SPILL					
Monocacy	No results.	6.0×10^5	3.5×10^5	1.5×10^5	9.0×10^1
BELOW SPILL	Agar was				
Parker Ford Br.	contaminated.	2.8×10^6	5.6×10^6	1.5×10^6	4.6×10^3
Valley Forge Br.		no sample	no sample	no sample	no sample
			30 July 1972		
ABOVE SPILL					
Monocacy	5.0×10^5	2.9×10^6	3.1×10^6	4.6×10^5	4.3×10^2
BELOW SPILL					
Parker Ford Br.	1.0×10^6	9.7×10^6	9.0×10^6	4.6×10^5	2.4×10^3
Valley Forge Br.	2.4×10^5	8.0×10^5	3.9×10^6	1.5×10^5	9.0×10^1

Appendix VI-5. Stomach contents of fishes collected from the Schuylkill River in winter 1972 and summer 1973

Winter 1972-73

Species	Above Spill		Below Spill	
	No. of Stomachs	Contents	No. of Stomachs	Contents
White sucker	6	100 ± Diptera pupae	1	100 ± Diptera pupae
	8	Empty	4	Empty
Brown bullhead	1	1 unidentified fish	1	1 Diptera larvae vertebrate hair mud
	4	Empty	1	3 Diptera larvae 2 Diptera pupae Mud
			3	Empty
Crappie	None captured		3	1 unidentified fish
			2	Empty
Bluegill	2	1 unidentified fish	None captured	
	1	1 unidentified fish 1 water boatman (Coroxidae)		
	2	Empty		

Appendix VI-5 (continued)

Summer 1973

Species	Above Spill		Below Spill	
	No. of Stomachs	Contents	No. of Stomachs	Contents
White sucker	1	unidentified organic material	1	Gravel
	1	Gravel	4	Empty
	3	Empty		
Brown bullhead	1	45 Diptera larvae	2	Fish scales
	1	100 Diptera larvae	1	Fish bones
	4	Empty		Mud
			1	Fish skeleton
				Algae mat
			1	unidentified fish (13mm)
			1	Empty
Crappie	1	11 Diptera larvae	2	Fish scales
	1	25 Diptera larvae unidentified organic material	1	insect appendage fish scales
	1	1 Diptera larvae insect appendage unidentified organic material	1 1	Insect appendage Empty
	1	6 Diptera pupae 4 Diptera larvae insect appendage		
	3	Fish remains		
	1	Empty		

Appendix VI-5. (continued)

Note: Most Diptera larvae observed in fish stomachs were members of the family Psychodidae. Diptera pupae were not further identified. It is probable that many were members of the families Tendipedidae and Ceratopogonidae.

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